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Geoarchaeological Assessment of Horseshoe Cave (24RB1094, Rosebud County, Montana

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GEOARCHAEOLOGICAL ASSESSMENT
OF HORSESHOE CAVE (24RB1094),
ROSEBUD COUNTY, MONTANA

By

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Regardless of all of the expertise and assistance supplied by those acknowledged above, errors, mistakes, and failures in critical thinking will surely be found. On that note, the responsibility for any such flaws is mine and mine alone.

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Geoarchaeological Assessment of

Horseshoe Cave (24RB1094), Rosebud County, Montana

Dr. Douglas MacDonald, Chair

Abstract

Horseshoe Cave is located south of Ashland, Montana and at the northern end of the Powder River Basin. Its earliest documented human use and occupation dates to 2,000 years before the present. Evidence of that past use and occupation includes diagnostic bone and stone tools, hearth features and animal remains. The geoarchaeological investigation of this sandstone cave site reveals the cave host rocks to be sandstones of the Tongue River Member of the Early Tertiary Fort Union Formation. Results of the geoarchaeological inquiry demonstrate that a difference in the calcite cementation between the two host sandstone units is the leading geologic factor in the creation of the cave. The cap-rock material is found to contain twice the amount of calcite cement than does the underlying cave-forming wall-rock unit. This difference in hardness allows both gravity and water to remove the much softer sandstone to form a cave feature that today is some 7 m wide and 3 m high at its opening and that extends some 12 m to its back.

The cave forming process appears to have been initiated tens of thousands of years ago when the gradient between the cave floor and the adjacent drainage bottom was steeper than at present. The pace of cave formation appears to have all but ceased and the majority of materials currently being deposited on the cave floor are from the grain-by-grain disintegration of the surrounding sandstone, a sedimentary process augmented by the occasional rock fall and from fine grained clastic materials being blown into the cave during arid times. The annual sedimentation rate ranges between 0.3 and 0.5 mm.

A sieve analysis of a 1.35 m column of sediment, which spans some 2000+ years, indicates that the past climatic regime of the sediments found in the cave collection includes at least four periods of warm and dry conditions, periods delineated by an increase in fine-grained sediment. When the arid patterns are overlain on wall profiles containing cultural features it is apparent that none of these features coincide with the dry intervals. This is an association that strongly suggests the area immediately surrounding Horseshoe Cave was not as favorable an environment as might be found along the larger regional drainage bottoms or the foothills of the Big Horn Mountains of Wyoming and the Black Hills of South Dakota.

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INTRODUCTION

Horseshoe Cave (24RB1094) is located south of the community of Ashland, Montana. Ashland is a small rural community located in the state's southeastern corner (Figure 1). Horseshoe Cave or rockshelter is found in the Early Tertiary sandstone rocks of the Tongue River Member of the Fort Union Formation. The findings of past archaeological investigations point to a use or occupation period that commenced at least as early as 1,000-1,800 years ago (Fisher 2010a:10). This time-period corresponds to Frison's (1991:24) Late Plains Archaic and Late Prehistoric.

A large portion of the cave site is situated on private ground, and the remainder is owned by the U.S. Government and administered by the United States Department of Agriculture-Forest Service. The local administrative unit is the Ashland Ranger District of the Custer National Forest in an area generally referred to as the Tongue River Breaks-Poker Jim area.

The focus of this report is a presentation of the geoarchaeological work that I conducted in support of Dr. John (Jack) Fisher's investigations at Horseshoe Cave. His investigations were conducted during the 2008, 2010 and 2011 field seasons.

My primary goal in this paper will be to answer several geologically-oriented questions raised by Dr. Fisher (2010a:14): <u>first</u>, what geologic process formed Horseshoe Cave; <u>second</u>, what is the rate of sedimentation within the cave; <u>third</u>, what are the sources of sediment found within the cave; <u>fourth</u>, how does the sedimentological and /or depositional setting within the cave differ from that outside the cave; and, <u>fifth</u>, what is the nature of the depositional variability across the cave?

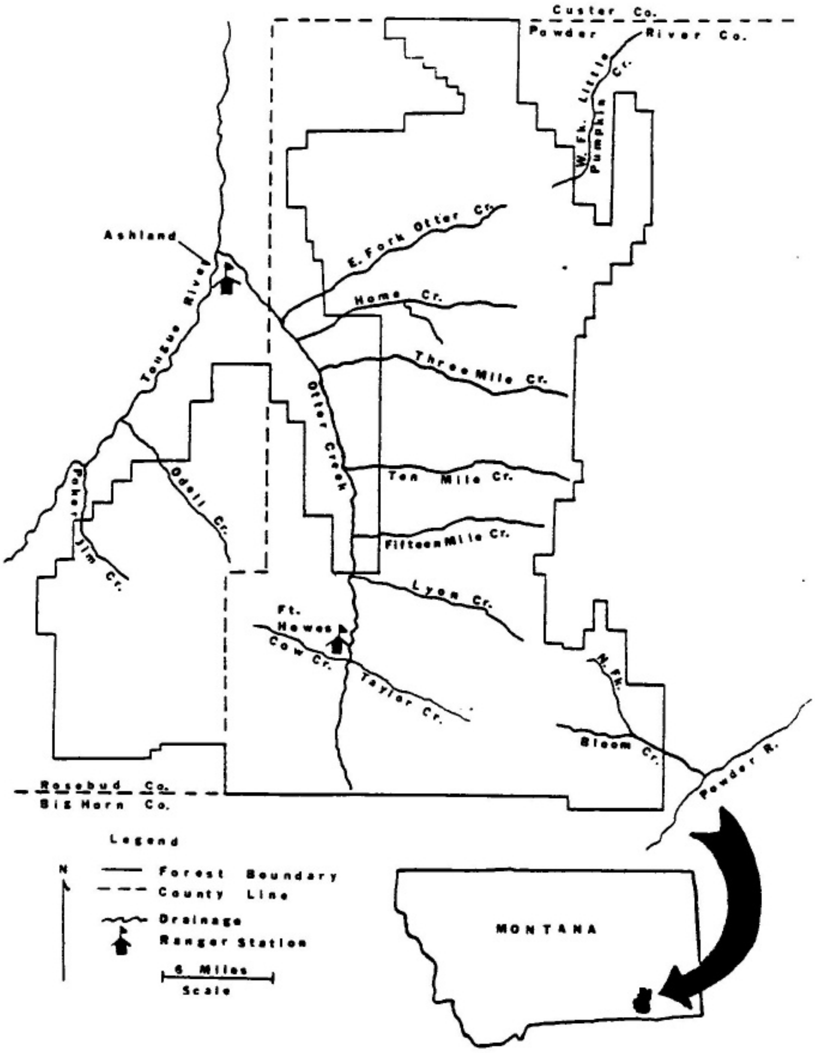


Figure 1. Generalized map of the Ashland Ranger District of the Custer National Forest in southeastern Montana. From McLean 1983:Figure 1.

While these five questions will be the focus of this paper, they will not be the only subjects addressed. I will also attempt to identify any geologic attributes that might have influenced human use of the cave and its surrounding area. This report will also identify any unique geologic features found within the cave and its surrounding area, features that may or may not have any anthropological relationship or significance.

RESEARCH TEAMS

2010 Investigation

The 2010 primary research team, those individuals that were the main contributors to the investigation phase from May 26 to June 4 consisted of Dr. John (Jack) Fisher, project team leader, Associate Professor of Anthropology, Montana State University (MSU), Bozeman, Montana; Scott Carpenter, assistant team leader and project photographer, professional archaeologist, *InteResources Planning, Inc.*, Bozeman, Montana; Jane Connors, project research assistant, excavation and survey, undergraduate student of anthropology, MSU, Bozeman; Madison Earll, project research assistant, excavation, undergraduate student of bio & neurosciences, MSU, Bozeman; Clint Garrett, project research assistant, excavation and survey, Bachelor of Arts (BA) of Anthropology, MSU, Bozeman; River Lovec, project research assistant, excavation and survey, BA of Anthropology, MSU, Bozeman; Norman Smyers, project assistant, geoarchaeological investigations, excavation support and survey, professional geologist (retired) (State of Minnesota Professional Geologist Licensure #30121), Master of Science in Geology, San Diego State University, graduate student of Anthropology, University of Montana, Missoula, Montana.

The following individuals who also, for shorter periods of time, provided onsite project assistance included: Mike Bergstrom, Archaeologist, Custer National Forests, Billings, Montana; Nancy Mahoney, adjunct professor of anthropology, MSU, Bozeman; Ivy Merriot, part-time student of anthropology, MSU, Bozeman; Scott Raznoff, undergraduate student of anthropology, MSU, Bozeman, and summer intern archaeologist for the Gallatin National Forest, Bozeman;

Megan Thornton, undergraduate student of anthropology, MSU, Bozeman; and Wendy Roberts, contract herpetologist/wildlife biologist, Bozeman.

2011 Investigation

The 2011 investigation team consisted of Dr. John (Jack) Fisher, project team leader; William (Bill) Eckerle, registered Professional Archaeologist/Professional Geologist (Wyoming and Utah), principal of Western GeoArch Research, Salt Lake City, Utah; Margo Eckerle, research assistant; Western GeoArch Research, Salt Lake City, Utah; Norman Smyers, project assistant; Scott Raznoff, BA of Anthropology, MSU, Bozeman, research assistant.

RESEARCH DESIGN AND INVESTIGATIVE STRATEGY

Research Design

The research design and investigative strategy of the 2010 Horseshoe Cave investigation was largely shaped by several questions raised by the 2008 investigation: what was the frequency of occupation and use of the Horseshoe Cave site; what was the time-depth of the human use of the cave site; what types of activities did past occupants carry out there; and what internal variations, if any, existed in the use of space within the rockshelter? Several of these questions have a direct relationship to the geologic questions raised by Dr. Fisher (2101a:14) as a result of his 2008 investigative work.

The objective of the 2011 investigation was to review the sedimentological history of a portion of the cave strata to determine if it held any clues as to the paleo-environmental conditions at the cave site and, possibly, how such conditions may have influenced human occupancy and use of the site.

Investigative Strategy and Methodology

Unit Excavations. In 2010 the unit excavation work, in part, was an extension of the work completed by Fisher in 2008. The 2008 work consisted of two units (1 and 2), each 2 x 1.5 meters in size, opened within the interior of the cave. These two units were joined contiguously to form a trench 4 x 1.5 m in size (Fisher 2010a:9). To avoid any confusion with this previous work, Fisher decided to designate the first unit of the 2010 investigation as Unit 3 with any additional units opened to numerically follow in sequence. In other words, the next unit after Unit 3 would be designated Unit 4 and so on.

The 2011 investigation was somewhat limited both in scope and time due to severe and adverse weather conditions. Activity was limited to the re-opening of 2008's Unit 2 and then the removal of a column or channel sample at the southwest corner of the unit's south wall.

Site Survey. The only site survey work addressed in this report is limited to that done during the 2010 investigation. This work was limited to the North Fork of Poker Jim Creek drainage basin.

The principle objectives of this site survey work were, first, to identify sites of past occupation that may or may not be related to the use of Horseshoe Cave; and, second, to locate cave or rockshelter sites that potentially could have been seen used for human use.

In addition, the findings of the survey work were viewed as means to gauge the frequency of sites similar to Horseshoe Cave and to test how unique or commonplace Horseshoe Cave might or might not be with respect to similar sites within southeastern Montana. In this regard, the task was to look for rock shelters or caves that might be of similar size and that potentially offer comparable protection from adverse weather conditions, and where the time period of occupation might be similar to that of Horseshoe Cave's.

GEOLOGIC FIELD AND LABORATORY ANALYSIS AND METHODS

Field-Level Work and Analysis

2010 Investigation. A *Magellan SporTrak™ Pro GPS* (Global Positioning System) receiver was used to provide a geographic location for various sites and features visited during the 2010 investigation. Location data was recorded in both latitude and longitude and Universal Transverse Mercator (UTM) units.

A *Brunton* pocket transit was used to measure the bearing of cracks and fissures and to determine the strike and kip of sedimentary rock units.

Onsite or field-level inspections of rock, soil and screened materials was accomplished using a *Bausch & Lomb 10X Coddington* hand lens.

Following *U.S. Soil Conservation Service* (now *the Natural Resources Conservation Service*) guidelines, a *Munsell* soil color chart (book) was used to classify the colors of the cave-forming wall and cap rock units, the soil units examined in an excavation well outside the cave entrance, screened excavation materials, and archaeological specimens.

A 10 inch soil probe was used to take shallow soil samples.

Soil types were classified using a United States Department of Agriculture (USDA) Soil Texturing Field Flow Chart manufactured by the *Midwest Geosciences Group*.

All collected samples were placed in new *Ziploc* brand plastic bags. Each bag was labeled on its outside with a permanent black felt marking pen and sealed with a protected duplicate label placed inside the bag.

Samples or rock and sieved materials that I collected taken during the 2010 investigation were marked with a code that indicated the site, the year, month and day the sample was collected. For example, the second sample collected on May 31, 2010, was labeled HSC-101531-2. In my system, "HSC" stood for Horseshoe Cave; "10" for the year; "05" for the month; "31" for the day it was collected; and the number "2" for the sample's order of collection on the given day.

The samples taken during the 2010 investigation were divided into three splits. One split was given to Dr. Fisher for his purposes and possible analysis by his University colleagues within the Earth Sciences Department at Montana State University, Bozeman. I retained the other two splits for my future study.

2011 Investigation. The principle objective of the 2011 investigative work was to obtain a channel sample from the southwest corner of the south wall of Unit 2, a unit that was originally opened in 2008. In late May 2011 and prior to the arrival of all of the 2011 research team members, personnel from the Ashland Ranger District fire crew removed the backfill from Unit 2. On May 25, the 2011 research team cut a channel sample from the southwest corner of the south wall of the Unit (see Appendix A, Unit 2 South Wall profile).

The length of the channel sample area measured approximately 135 cm (53 in.) from the ground surface to the base of the excavation. Along this length, two channel samples were taken with a bulk area in-between the two. Column A was along the left-hand side and Column B from along the right-hand side of the sampling area. A sample was taken from each 5 cm interval with the depth of collection extending approximately 10 to 12 cm into the wall of the unit.

Each sample was put into a new *Ziploc* brand plastic bag and labeled on the outside of the bag with a black felt marking pen and inside with a protected duplicate label. Bill Eckerle took one of the splits (Column A) and I took the other (Column B) for later processing and analysis.

At a depth of approximately 16 cm (6 in.) below ground level a horizontally oriented sediment optically stimulated luminescence (OSL) core sample was taken from the back portion of Column A. If funding becomes available, this sample will provide a "control" date for the sediment at this level within the unit (Fisher 2011:10).

Laboratory Analysis

2010 Samples. At the University of Montana's Anthropology Department, I subjected the collected rock and field-screened materials to a detailed visual inspection under a binocular microscope with magnification levels of 10, 20 and 40X.

Both solid rock specimens and disaggregated rock were used in this examination to determine average grain-size, grain shape, and the (percentage) mineral composition of the grains making up the collected rock samples. A *Geotechnical Gauge* and a *Sand-gauge* were used in making these determinations; both gauges were manufactured by the W.P. McCollough Company of Beltsville, Maryland.

Because there were no apparent significant physical differences between the cave's wall-rock and cap-rock units, four samples of those two units were sent to *Spectrum Petrographics,* *Inc.*, in Portland, Oregon, for thin-section preparation. Spectrum was instructed to prepare four thin-section slides. In order to enhance the presence of any calcite cement one-half of each thin-section was subjected to a (blue) calcite-stain while the other half was left unstained.

Upon receipt of the prepared thin-sections and with the aid of Dr. Marc Hendrix, Professor of Geology at the University of Montana, the thin-sections were then analyzed at 25X magnification using the Department's *Leica* DMLP model petrographic microscope. The samples were examined under both white and polarized light.

2011 Samples. In examining both the unscreened and screened samples, I used both a *Bausch & Lomb 10X Coddington* hand lens and a *Swift M27 LED-124* stereoscopic microscope with 10, 20 and 40 power magnifications.

Prior to screening or sieving, a *Munsell* soil color chart (book) was used to classify both the wet and dry color of each interval sample and a No. 693 Hellige-Truog Soil Reaction (pH) Tester kit for the pH of the interval.

The interval samples were dry-screened or sieved using a stack of six 8-inch *Newark* brass testing screens. The testing screens used for the sieve analysis with their size characteristics are shown below in Table 1.

In practice, Mesh size 10 collected all materials of 2.00 mm and above in size; and, in similar fashion, a collection pan placed at the bottom of the sieve stack collected those materials smaller than 0.0625 mm, here an undifferentiated silt and clay fraction. Waters (1992:15-28) provides an excellent overview regarding the study of clastic sediments and their characteristics.

Table 1. Size characteristics of sieve screens used for this study

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Wentworth Size Classes
10	2.00	-1.0	Granule
18	1.00	0.0	Very coarse sand
35	0.50	1.0	Coarse sand
60	0.25	2.0	Medium sand
120	0.125	3.0	Fine sand
230	0.0625	4.0	Very fine sand

Finally, in order to establish the weight percent of each size-fraction, each was weighed using an *Ohaus Triple Beam Balance* that allowed measurements to 0.1 of a gram.

Upon completion of screening, each size fraction was examined by hand lens and microscope for the overall shape of the grains, the mineral composition or makeup of the grains, and the presence or absence of grain frosting.

PREVIOUS WORK

Archaeology

Six reports have been produced regarding the archaeological aspects of Horseshoe Cave. The first of these reports is by Gary McLean (1976) who conducted the first detailed investigation of the cave in 1976. McLean was the principal investigator for the University of Montana team of archaeologists that conducted this first formal investigation. The results of this study were submitted to the U.S. Forest Service in 1976 as an unfinished 108-page report.

Briefly, the units opened for this investigation yielded stratified deposits that contained multiple hearth features, stone and bone artifacts, and a Scottsbluff projectile point that appears to have been reworked (Fisher 2010a:1-2; Bonnichsen and Keyser 1982:140-143). The details and findings of this investigative effort will be given more attention below in the section dealing with the excavation units that have, so far, been opened at Horseshoe Cave.

Bonnichsen and Keyser (1982:137-144) provide a discussion of three small projectile points they claim are associated with the Paleo-Indian Cody Complex, the reworked Scottsbluff point is one of the three analyzed in their article.

Two reports of notice with references to Horseshoe Cave have been issued by the USDA-Forest Service. While both reports are oriented toward the overall cultural history of the lands it manages in southeastern Montana they do offer information regarding Horseshoe Cave and its setting. The most comprehensive of these is *The Prehistory of the Custer National Forest* by Michael Beckes and James Keyser (1983). This report provides a summary knowledge of Horseshoe Cave and notes it was Beckes who first reported on its existence in 1973 with the filing of a formal site report in 1976 (Beckes and Keyser 1983:270). In this overview, Beckes and Keyser (1983:270) also offer some thoughts regarding the results of McLean's 1976 investigation and suggestions as to what other future investigative inquires might be pursued at the site. The second Forest Service report is by James Wettstaed (n.d) who provides additional thoughts and information regarding land used patterns in southeastern Montana; this report is based on work completed for a 1989 Master of Arts degree in Anthropology from Wichita State University.

After a hiatus of some 32 years, Dr. Fisher conducted the next formal investigations of the site during the summers of 2008, 2010 and 2011. A summary of Fisher's 2008 activities and findings are documented in a brief unpublished report issued in April 2010. Two other unpublished reports follow in August 2010 and June 2011.

The 2008 activities at the site resulted in the opening of two units within the interior of the cave. The deeper of these two units extended to a depth of about 1.3 m. Find included several heath features, animal bones, lithic flakes, and one porcellanite projective point tentatively identified as a Besant (Fisher 2010a:9-12).

As mentioned above, the results of Fisher's 2008 helped define the path for the investigative trajectories that were undertaken in May and June of 2010. This work resulted in the opening of three units, one inside the cave, one at its drip-line, and the third some 20-30 meters northeast of the cave's opening (Fisher 2010b). None of these units yielded any pre-Contact era artifacts, only animal bones. Archaeological survey work conducted in the immediate area of the cave identified five archaeological sites, some with lithic scatter, a rock enclosure and one site, a substantial pile of rocks, a site that could represent a human burial (Fisher 2010b).

The 2011 work at the site was brief due to heavy rainfall and flooding. Work at the site was limited to removing the backfill from Unit 2, which as dug in 2008, and, for the purpose of establishing some paleo-environmental background for the cave's history, the removal two channel samples from the south wall of the unit. The analysis of one of these two samples will be discussed in detail below in the Excavation Units section. In addition to the two column samples, a horizontally oriented sediment core was also taken from the south wall for dating the sediments by using optically stimulated luminescence (OSL) (Fisher 2011).

Geology

The geologic literature reviewed for this report was largely regional in nature and decidedly focused on the plentiful energy resources found in the Powder River Basin--namely coal, oil and gas. The Powder River Basin is a designation that is applied to a large swath of north-central Wyoming and southeastern Montana. Its connotation is geographic, geomorphic, geologic and hydrologic in both application and character. Horseshoe Cave lies at the northern tip of this north-south elongated basinal feature.

The regional reports reviewed and used for this report include Ayers (1986), Brown (1993), Flores (1986 and1987), Johnson and Pierce (1990), Kent (1986), Merin and Lindholm (1986), Pocknall and Flores (1987), and Seeland (1993). These discussions offer detailed information regarding the sedimentological, stratigraphic, tectonic, and coal depositional histories of the Powder River Basin.

A partial exception to this mostly regional coverage of the Powder River Basin is the Hydrogeology of the Ashland Ranger District, Custer National Forest Southeastern Montana by Wheaton et al. (2008). The introductory pages of this Montana Bureau of Mines and Geology Open-File Report (570) provide an excellent summary of the area's climatic and topographic attributes. This report also provides some detailed specifics regarding the geology, soils, hydrologic and mineral resources of the Ashland Ranger District of the Custer National Forest of which the Tongue River Breaks-Poker Jim area is but a small fraction of the District's 435,000 acres. This report provides important geologic details, some of which may have a direct bearing on Horseshoe Cave's geologic past that can be readily extracted from the publication's text and maps.

Finally, the roadside geology handbooks of Montana by Alt and Hyndman (1986) and Wyoming by Lageson and Spearing (1988) offer broad and generalized geologic overviews of the Powder River Basin. At best, these two guidebooks offer a good beginning point for those unfamiliar with the basic physical parameter and geologic history of this part of the Northern Great Plains.

PHYSICAL SETTING

Geographic Description

Horseshoe Cave is located some 25 km (16 mi.) south of the community of Ashland, Montana and in the North Fork of Poker Jim Creek which is one of several small creeks draining the western flank of a large area of elevated and rugged country known as the Tongue River Breaks. The cave sits at an elevation of approximately 1,057 m (3,470 ft.) above mean sea-level.

Figure 2. Horseshoe Cave (red arrow). S. Carpenter/IRP, © photograph, 2010.

The cave site is situated on an east facing hillside of small tributary to the North Fork of Poker Jim Creek. The cave is somewhat obscured by vegetation and several large rocks that litter the base of the scarp edge along which Horseshoe Cave is found (Figure 2).

Physiography and Topography

Horseshoe Cave lies within the Great Plains Physiographic Province, a large portion of central North America that is bordered on the east and south by the Central Lowland, Ouachita Province-Ozark Plateaus, and the Coast Plain regions of the central United States (Hunt 1967:203-221). To the west, the Great Plains Province abuts up against the Rocky Mountain Province, the latter a several hundred kilometer/mile wide zone of high mountains and valleys that begins far to the south in Mexico and continues almost unbroken, past Horseshoe Cave, all the way north and through Canada to the Artic Ocean (Hunt 1967:8-9 and 221-226). Except for isolated occurrences of igneous and metamorphic rocks found in Montana and around the Black Hills of northwestern South Dakota, the surface geology of the Great Plains Province consists chiefly of clastic sedimentary rocks—sandstone, shale and claystone (Hunt 1967:222-223).

In large part, the materials that make up the sedimentary surface rocks in and around north-central Wyoming and southeastern Montana or that region in which Horseshoe Cave is found have their origins in several of the mountain ranges of the nearby Rocky Mountain Province. In effect, the Horseshoe Cave site lies very near the seam between the Great Plains and Rocky Mountain Provinces and within a geographic, geologic and topographic feature known as the Powder River Basin (Hunt 1967:8-9 and 221-223).

Horseshoe Cave is located in an area composed largely of horizontal sedimentary rocks of the Tongue River Member of the Fort Union Formation. The Fort Union Formation is a thick Early Tertiary sequence of alternating beds of sandstone, claystone, shale and coal. In several areas the coal has been burned and in these areas it is not uncommon to encounter a brick-red rock known as clinker.

As noted by Wheaton et al. (2008:5) the countryside in and around Horseshoe Cave has been broken and cut into highly eroded river breaks. Horseshoe Cave sits on the northern edge of the North Fork of Poker Jim Creek. This creek is but one of the many smaller drainages that have cut a large upland area into a badlands country of narrow canyons and sharp drainage divides; this an area that has been designated by the USDA-Forest Service as the Tongue River Hiking and Riding Area. In the area of Horseshoe Cave, the North Fork drainage has a width of about 0.20 km (⅛ mi.).

Figure 3. View east up the North Fork of Poker Jim Creek. Photograph by Norman Smyers, 05/31/2010.

Where the valley walls are constructed of sandstone outcrops, the division between valley and hillside is somewhat steep if not almost vertical; where the rocks are primarily softer silts and clays the slopes are more gentle and rounded. Where thick beds of sandstone Crop out and dominate the stratigraphic sequence, the slope break is often times abrupt, a characteristic that can favor the formation of overhangs, rockshelters and caves.

The floor-level of the opening to Horseshoe Cave is approximately 12 m (40 ft.) above that of the North Fork valley bottom and about 4 to 5 m (12-15 ft.) above the base of the unnamed intermittent creek that lies some 20-30 m (60-90 ft.) directly east of the cave opening.

The land directly north of Horseshoe Cave rises steeply over a distance of about 1.6 km (1 mi.) to a drainage divide with Poker Teechee Creek, a divide with an elevation in excess of 1,220 m (4,000 ft.) above mean sea-level; this represents an elevational change of more than 183 m (600 ft.) in less than 2 km (1.25 mi.).

Climate

Based on climate data collected from 1961 through 1990 the average annual precipitation across the Ashland Ranger District was between 356 to 457 mm (14-18 in.) (Wheaton et al. 2008:6). However, as with any area that has the degree of topographic relief displayed by the countryside around Horseshoe Cave, precipitation amounts can vary widely. Given the lower elevational status of the cave area, the average-annual amounts at the cave are probably at the lower end of the above annual-average range. The annual-average free water-surface evaporation rate for the Ashland Ranger District is estimated at about 864 ml/year (34 in. /year) (Wheaton et al. 2008:9).

By most standards, these levels of annual precipitation and evaporation would categorize the Ashland Ranger District as semi-arid. However, the availability of moisture to plants in the study may have more to do with the makeup of the substrate than the amount of annual precipitation. In short, clay and shale substrates are considered “tight” because they do not their available moisture to plants, whereas sandstones with sufficient porosity offer a more favorable environment for larger plant species such as shrubs and trees, vegetation that can require a large volume of moisture to meet their needs.

The nearest appearing year-round water source to Horseshoe Cave is the North Fork of Poker Jim Creek which lies approximately 185-250 m (600-800 ft.) south of the cave.

During the 2010 investigation, flowing water was noted in the North Fork of Poker Jim Creek. I visually estimated its flow at about 1.0-1.5 l/second (1.0-1.5 qt. /sec.). However, during the spring of 2010 moisture conditions across the entire state of Montana and northern Wyoming were wetter than normal. Therefore, it is quite possible that during drier or droughty times the North Fork does not carry water in the vicinity of Horseshoe Cave.

For the greater Ashland area, the annual mean temperature is 7.4 °C (45.4°F). The average-annual range is from -44° to 42°C (-47° to 108°F), with the coolest days occurring in December and January and the warmest months being July and August (Wheaton et al. 2008:6).

While daily wind speeds for the Ashland Ranger District average about 11 km/hr. (7 mi. /hr.), winds as high as 121 km/hr. (75 mi. /hr.) have occurred occasionally (Wheaton et al. 2008:6).

Vegetation

As noted above, the vegetative cover of the North Fork of Poker Jim Creek drainage appears in large part to be controlled by the substrate upon which vegetation grows. The annual precipitation alone can not account for the dramatic differences between adjacent forested and grassland areas.

Using the ten ecozone classification system referenced by Beckes and Keyser (1983:57-66), several ecozone types can be applied to the area in and around the Horseshoe Cave site. The ecozone types here would include a combination of the Grassland Parks/Upland Prairie/Creek Bottom-Mixed Deciduous Tree/Shrub ecozones, the Scoria-Sandstone Outcrop ecozone, and the Dry Slope Ponderosa ecozone.

With respect to Horseshoe Cave and the area immediately surrounding the site, a combination of characteristics associated with the Grassland Parks/Upland Prairie/Creek Bottom-Mixed Deciduous Tree/Shrub ecozones best describes the valley in which the North Fork of Poker Jim Creek is located. This is an area dominated by grasses and small to moderate sized shrubs that are broken in places by an occasional tree or small stand of trees. This moderate cover of trees and other large shrubs may well be due to the fine grained silt and clay substrate floor of the valley. Again, as noted above, silts and clays do not readily release interstitial water to vegetation. However, this is not true of the Horseshoe Cave site. Here the substrate is largely sandstone, a rock that readily releases its contained moisture to vegetation.

Thus, the area immediately in and around Horseshoe Cave supports a good cover of Ponderosa pine and large shrubs.

The more common grasses in the Grassland Parks/Upland Prairie ecozones include Idaho fescue (*Festuca idahoensis*), green needle grass (*Stipa viridula*), western wheatgrass (*Agropyron smithii*), and Big bluestem (*Andropogon geradii*); common shrub species include silver sage (Artemisia can) and big sagebrush (*Artemisia tridentata*) (Beckes and Keyser 1983:57-58, 62-63, and 65-66).

GEOLOGY

Regional

Horseshoe Cave and its immediate surroundings lie at the north-end of the Powder River Basin. The basin is a structural feature initiated by the Laramide Orogeny, a tectonic or mountain building event that spanned some 40 million years (Figure 4). In this area of North America, the orogeny began some 80 million years ago during the Late Cretaceous and continued into Early Tertiary times when it came to a close in the Eocene Epoch about 40 million years ago. During the interval of 40 to 55 million years ago rocks of the Fort Union Formation, the geologic unit of interest here, were deposited in the Powder River Basin (Brown 1993:L2); Lageson and Spearing 1988:*ix*, 15-17; Flores 1986:80; Kent 1986:115-117; Ayers 1986:1651; Alt and Hyndman 1986:153).

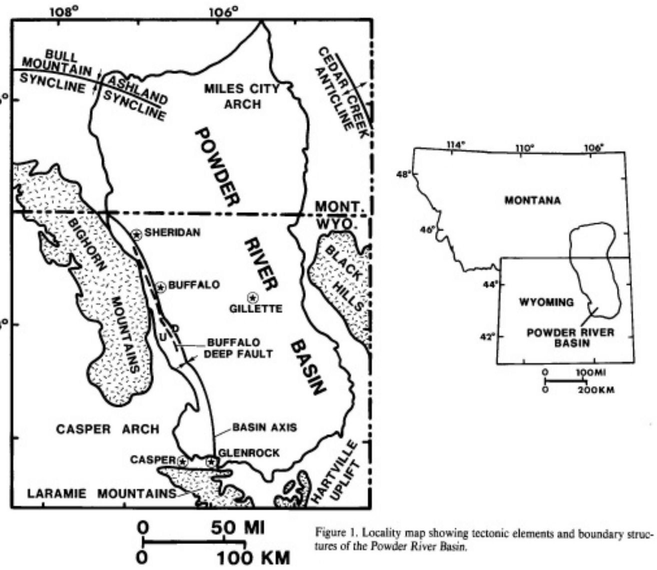


Figure 4. Structural setting of the Powder River Basin. From Flores 1986:Figure 1.

Johnson and Pierce (1990:34-35) describe the depositional environment for the Fort Union Formation as a broad and low lying alluvial plain consisting of a series bird of large coalescing alluvial fans laced with slow-moving rivers that meandered across the plain until they reached a deltaic system with multiple bird-foot style branches that, eventually, delivered their contents into a large and retreating inland sea. That inland sea lay to the east of the Powder

River Basin; and during the Fort Union time, the sea's western margins was retreating eastward to what is today the central regions of the states of North and South Dakota.

The lowland areas of today's Coastal Plain Physiographic Province of the southeastern United States can be considered a likely modern-day counterpart to what the eastern slope of the Rocky Mountains might have looked like some 40-55 million years ago during Fort Union times (Hoganson and Murphy 2003:26-30; Alt and Hyndman 1986:183; and Hunt 1967:8-9 and 137-156). Flores (1986:95) provides the Kutai Basin that is drained by the Mahakam River on the island of Kalimantan (Borneo), and the Rio Paraiba do Sul in the State of São Paulo, Brazil as two additional modern-day examples of what the Powder River Basin may have looked like at this time.

Since at least the Late Cretaceous, the Powder River Basin has received its runoff from the surrounding mountains and highlands. This runoff has carried with it bits and pieces of these mountains and highlands into the Powder River basin. During the Early Tertiary, this runoff built up the thick sedimentary sequence that today is known as the Fort Union Formation. This formation consists of more than 1,500 m (5,000 ft.) of sandstone, shale, claystone and coal (Hoganson and Murphy 2003:26-30; Ayers 1986:1651; Flores 1986:80; Hunt 1967:222-226).

The Fort Union Formation has been subdivided into three members that are, in ascending order, the Tullock, the Lebo shale, and the Tongue River (Figure 5). While all three of these units in the Powder River Basin contain stringers and/or beds of coal, the Tongue River Member contains the greatest number of coal beds that can be mined and marketed at a profit (Johnson and Pierce 1990:21).

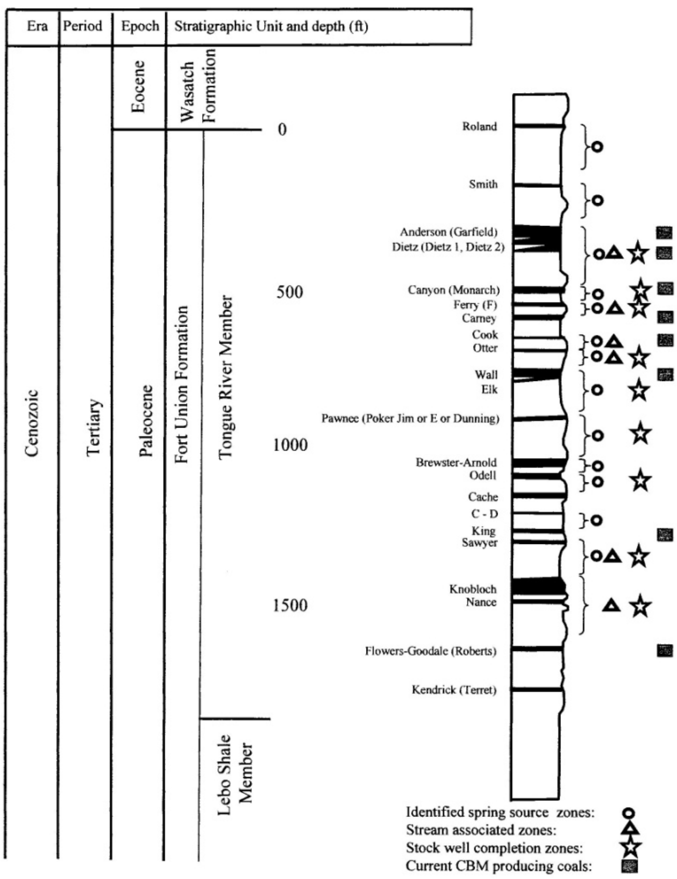


Figure 5. Stratigraphic column for the Fort Union Formation. From Wheaton et al. 2008:Figure 5.

The coal beds started with thick stands of vegetation that grew in the backwater areas and sloughs that lined many of the braided-stream channels of that Early Tertiary Powder River basin drainage system. Here there was an almost continual rain of vegetation falling onto a sometimes swampy forest floor.

Overtime, this fallen vegetation would accumulate to form a thick deposit of peat. Frequently this entire assemblage of vegetation, peat, sand, silt, and clay would be buried and compressed by the weight of the overlying sediments to form coal (Johnson and Pierce 1990:32-35; Pocknall and Flores1987:141-144; Flores 1987:84-88 and 1986:82-86).

Over time the meandering system of the streams and rivers that crisscrossed the alluvial plain could dramatically change the environmental conditions at any location within the basin to something significantly different. For instance, at one time a site may be a river bottom; with a slight change in river direction the site would become a dry river terrace; and, then, a significant flood-event would later transform the same site into a backwater swamp. As evidenced by the variations in the rocks that make up the Fort Union Formation, these environmental scenarios and their associated sedimentary characteristics were replicated multiple times during Fort Union times (Flores 1986:98-100). These radical shifts in environmental conditions can explain how the characteristics of one rock unit can differ so markedly from a rock unit above or below it.

The sediments that formed the alluvial plains, the banks of the rivers, and the substrate upon which the coal vegetation grew originated in the mountains and highlands surrounding the Powder River Basin. Major contributions of sediments came from the Big Horn Mountains along the Basin's western margin; the Black Hills along its eastern margins; and the Laramie Range and Hartville Uplift along its southern edge (Brown 1993:L2; Johnson and Pierce 1990:21-23; Lageson and Spearing 1988:90-120; Flores 1986:80-86; Kent 1986:115-117; Ayers 1986:1651-1652; Merin and Lindholm 1986:128-130).

With the exception of the Hartville Uplift, the rocks at the cores of the above mountain ranges are composed of similar mix of Precambrian granite and gneiss that is rich in quartz and feldspar with some minor amounts of such mafic minerals as biotite and muscovite mica, epidote, augite, and horndblende. This commonality among the parent rocks makes the task of sourcing the origins of the deposits in any one area particularly difficult. Any judgment rendered as to provenance is based largely on proximity to the suspect source area, current drainage patterns, and accepted principles and knowledge about paleo-drainage patterns (Kent 1986:115-117; Ayers 1986:1651-1652). In their study of upper level Tongue River Member sediments, Merin and Lindholm (1986:128-130) posited that the particles of detrital calcite and dolomite they found in these deposits were derived from the Paleozoic carbonate sequences that are found along the eastern flank of the Big Horn Mountains; this is a reasonable assumption considering that the proximity of their study area to the Big Horn Range was just a bit more than 160 km (100 mi.).

Minerals ground into a fine powder became the clay and silt rich units of the Fort Union Formation's three members, whereas the more resistant minerals persisted as larger fragments to form the sandstone and pebbly conglomerate units. As may be expected, the conglomerate units or those with larger clast sizes occur near mountainous or highland areas while the finer materials, such as moderate to fine sand, silt and clay are the dominant sediments found in the more central portions of the basin (Ayers 1986:1661). Since the depositional environment of the time largely consisted of slow and sluggish river systems, this scenario is not an unreasonable one.

However, the paleontological evidence supporting the existence of backwater sloughs and swamps suggests that there had to have been occasional periods of high-flow that would have pushed rivers over their banks to form the backwater areas that, again, paleo-botanical evidence suggests were vegetative rich swamps that frequently lined the rivers. The average grain size of mineral fragments carried by the rivers was seldom any larger than coarse sand (0.50 mm or 0.02 inches) (United Soil Classification System or USCS). In addition, the shape of the fragments and their associated depositional structures combine to suggest a depositional setting of flat terrain, low-gradient flow, and somewhat marshy conditions (Flores 1986:82-95; Kent 1986:115-117; Ayers 1986:1656-1670; Merin and Lindholm 1986:128-130).

Poker Jim Creek

The surface geology of the Poker Jim Creek drainage consists exclusively of the Tongue River Member of the Fort Union Formation. In fact, the Tongue River Member is the only geologic stratigraphic unit, other than Holocene or recent alluvium, within a 40 km (24 mi.) radius of the Horseshoe Cave site. Aside from these two geologic units, the nearest unit of either

Tertiary or Quaternary age is the Wasatch Formation (Eocene) which overlies the Fort Union Formation to the north, south and west of Horseshoe Cave (Vuke et al. 2001; Bergantino 1980a and 1980b).

The thickness of all three members of the Fort Union Formation increases as they trend south from Montana into Wyoming and toward the more (geologically) central portions of the Powder River Basin (Ayers 1986:1656-1665). On lands administered by the Ashland Ranger District, the Tullock Member is approximately 61-107 m (200-350 ft.) thick; the Lebo shale is between 61 and 91 m (200 to 300 ft.) thick; and the Tongue River Member in the southern portions of the Ranger District is more than 610 m (2,000 ft.) thick (Wheaton et al. 2008:15-16). Some of the coal beds in the Tongue River Member are up to 20 m (65 ft.) thick (Wheaton et al. 2008:15).

The dominant topographic feature within the Poker Jim Creek drainage basin is a high east-west trending ridge that lies just to the north of Horseshoe Cave. This ridge-line feature has an elevation of at least 200 m (600 ft.) above that of the floor of the Poker Jim Creek drainage. The south facing aspect of this ridge-system, which is approximately 2.5 km (1.5 mi.) in length, presents a steep and rugged slope made up of repetitious intervals of horizontally-bedded sandstone, claystone, mudstone and siltstone interrupted in places by bands of a dark red and orange clinker (Vuke et al. 2007).

Clinker, again, is the result of burning coal beds. Where these coal fires are especially hot, they will not only bake but actually melt the surrounding and overlying rocks to a point where the finished product resembles volcanic scoria (Hoganson and Murphy 2003:38-40). Often, in some places of the northern Great Plains, clinker is incorrectly referred to as scoria, a term more properly reserved for a rock associated with volcanic eruptions (Wheaton et al. 2008:16; Hoganson and Murphy 2003:38-41).

Figure 6. Porcellanite core found near Horseshoe Cave. S. Carpenter/IRP, © photograph, 2010.

If the rock unit adjacent to a burning coal bed is highly siliceous, the intense heat emitted by the fire can actually bake the shale to a point where, upon cooling, it forms a hard and glassy product known as porcellanite (Figure 6). Porcellanite is a material that was frequently used by pre-Contact people to fashion a stone tool which needed a sharp edge or point. Tools such as projectile points, scrapers and knives were often fashioned from porcellanite in southeastern Montana and northeastern Wyoming (Odell 2003:32; Frison 1991:46).

During one episode of site survey, both River Lovec and I found large porcellanite cores. These cores were found approximately 1.5 km (1 mi.) west of Horseshoe Cave in and around a set of hoodoos (Figure 7). Hoodoo is a descriptive term given by Thornbury (1954:70) to a pillar or rock feature that formed by the erosion of horizontal strata of varying hardness, in this case, hard sandstone overlying, apparently, softer and less well cemented sandstone.

Figure 7. Hoodoo structures west of Horseshoe Cave. Photograph by Norman Smyers, 05/31/2010.

Garrett and Lovec (personal communication, May 2010) revealed that they had also discovered several other porcellanite cores elsewhere in the North Fork drainage and had, as well, visited several of the clinker beds on the higher slopes of the canyon where they found in-place porcellanite materials. However, in their opinion, none of these sites displayed any evidence of having been used as a quarry (site) by pre-Contact peoples. Therefore, their discoveries offer little insight as to the material source(s) for the porcellanite artifacts that have been discovered at Horseshoe Cave and elsewhere in the drainage basin of the North Fork of Poker Jim Creek.

Horseshoe Cave Site

Using the stratigraphic column and coal outcrop map provided by Wheat et al. (2008:Figure 5 and Plate 1), I place the Horseshoe Cave site at a (stratigraphic) point about midway between the Pawnee and Wall coal beds—the Pawnee is located stratigraphically beneath Horseshoe Cave and the Wall is stratigraphically above the cave site. Stratigraphically, this would place the sandstones making up Horseshoe Cave in the middle portion of the Tongue River Member.

Interestingly enough, neither coal bed has any noticeable surface expression in and around Horseshoe Cave. The Pawnee lies hidden beneath the sandstone units that make up the cave structure and the softer sedimentary cover and alluvium that form the (adjacent) valley of the North Fork of Poker Jim Creek.

Figure 8. Wall coal beds located above Horseshoe Cave. Photograph by Norman Smyers, 05/28/2010.

Information provided by Wheaton et al. (2008:13) suggests that the Wall coal bed has a thickness of some 6 to 8 m (20 to 25 ft.). However, if this is the case for the stratigraphic sequence immediately above Horseshoe Cave, it is not readily apparent. The only evidence of Wall coal beds that I could find in the immediate vicinity of the cave site were several thin-stringers of heavily oxidized coal (Figure 8). On the other hand, even thick coal beds can sometimes be obscured by the effects of heavy oxidation that exposed coal frequently experiences and, as well, by a cover of silt and clay that is often washed down from overlying beds.

I found no porcellanite materials in these coal beds. However, small pieces of red to black porcellanite, ranging from 6-8 cm ($2\frac{3}{8}$-$3\frac{1}{5}$ in.) in length by 5-7 cm (2-2¾ in.) in width, can be found scattered along the bottom of the unnamed drainage directly east of Horseshoe Cave. Since no small pieces of porcellanite can be found on the hillsides in immediate vicinity of Horseshoe Cave it appears that their presence in this drainage bottom is due to intense storm runoff events have washed materials downslope from the hillsides to the north of the cave, hillsides that have thick beds of exposed clinker.

I find that Flores' (1986:83) floodplain facies description best fits with the geology that I found exposed at Horseshoe Cave. Here the small scale sandstone features consist of convolutions, ripple laminations (bedding), and small-scale cross laminations set in a sedimentary stratigraphic sequence often associated with calcite rich floodplain backwaters that frequently contain abundant evidence of past plant (coal) and animal life.

Depositional affinities aside, Flores (1986:88) offers, perhaps, what I consider to be one of the better snapshots of what the Horseshoe Cave area looked like during the interval in which the Wall coal zone was deposited:

> The depositional styles of both the Wall and Anderson-Dietz Coal Zones are similar to those of the Sussex coal zone in the southwestern part of the basin. Northeast-flowing meandering rivers built meanderbelts stabilized by forested, peat-forming backswamps to the west. Periodic shifts of channel position along these meanderbelts resulted in small scale expansion and contractions of backswamp margins that influenced splitting of the Wall and Anderson-Dietz coal zones.

PHYSICAL CHARACTERISTICS OF HORESHOE CAVE

Dimensions

Horseshoe Cave is tucked into a sandstone rock outcrop that curves around a bench-like terrace. For a little more than 0.75 km (0.5 mi.) this terrace-scarp can followed northwest-southeast along the north flank of the North Fork of Poker Jim Creek (Figure 2). The more prominent portions of this (sandstone) scarp average about 2-5 m (6-16 ft.) in height. Given the nearly horizontal nature of the sedimentary units in this area, this height appears to be a close approximation of the thickness of the sandstone unit in which the cave has been formed. On the other hand, I found no locations in and around the cave where the base of the cave forming unit was well exposed. Therefore, the cave forming sandstone unit could, in fact, be somewhat thicker than scarp height.

However, it should be noted that this scarp is composed both of the hard and soft sandstones into which the cave has been carved. The presence of soft sandstone in scarp like fashion is unusual unless it has been offered some protection from the forces of weathering and erosion by some harder overlying rock unit which, as will be discussed below, is the case here. As one walks up slope (north) from the North Fork and into the narrowing unnamed drainage that contains Horseshoe Cave, the scarp quickly diminishes in importance until it melts away into the more rugged hillside that, in itself, steepens to the north.

In terms of length or depth the cave extends nearly 12 m (36 ft.) from its drip-line to where it narrows down and, seemingly, disappears in triangular fashion into the sandstone rock from which it was formed (Figures 9-13). The cave opening or mouth is 7.5 m (24.6 ft.) in width

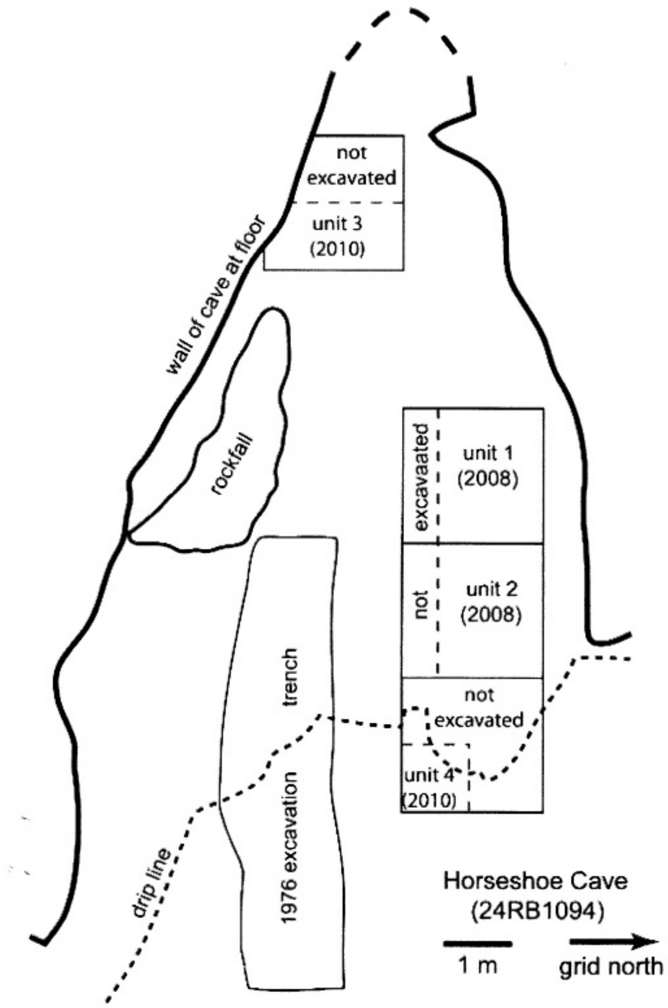


Figure 9. Plan view of Horseshoe Cave. Provided by Fisher in 2011.

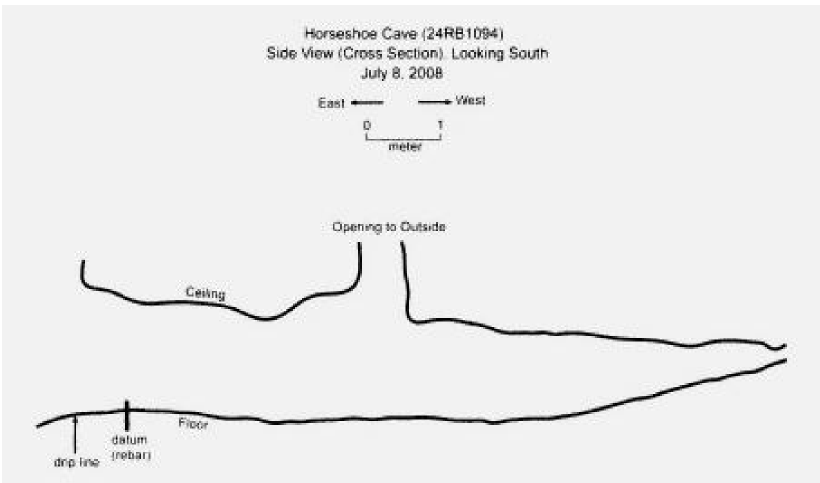


Figure 10. Cross-sectional profile of Horseshoe Cave. *Cave* opening or mouth is at the left side of profile. From Fisher 2010a:Figure 3.

Figure 11. Opening to Horseshoe Cave. Note the second person in front is standing in trench cut by McLean in 1976. Photograph by Norman Smyers, 05/27/2010.

Figure 12. Looking east out of Horseshoe Cave. Trench on right was cut by McLean in 1976. Photograph by Norman Smyers, 06/02/2010.

Figure 13. West end or back of cave. Note upward slope littered with vegetative debris and fallen pieces of wall and ceiling rock. Photograph by Norman Smyers, 06/02/2010.

and averages a little less than 2 m (6½ ft.) in height. Midway toward the back the cave width is 6 m (19.7 ft.) and the floor to ceiling height is approximately 1.2 m (3.9 ft.) (Fisher 2010a:4-6).

Form and Content

Ceiling and Walls. The cave has been fashioned by two noticeably different sandstone beds that have a total combined exposed thickness of roughly 3-3.5 m (9-12 ft.). A well-indurated (hard) cap-rock unit forms the roof of the cave; it is about 1.0-1.5 m (3-4 ft.) thick. The walls and floor of the cave are made up of a much softer sandstone unit that approaches 2-2.5 m (6-8 ft.) in thickness. The base of this wall and floor forming sandstone does not appear to be totally exposed anywhere in the vicinity of the cave, therefore its thickness could, in fact, be somewhat more than that reported immediately above.

Again, the cap-rock sandstone is well-indurated or hardened, thereby making it very capable of resisting physical disintegration (Figure 14). It displays fine cross-bedding laminations or, in this cave, bedding. Very likely, because of their durability pieces of cap-rock are the most common of the fall-rock material seen in and around the cave opening. This fall-rock occurs in a full range of sizes from small fragments that are less than 10 cm (4 in.) in length to several large boulder-sized blocks that are at least 2-3 m (6-10 ft.) long by 1.-2 m (3.6 ft.) in width and thickness. The results of a thorough inspection and analysis of both the wall and cap rock units will be provided below.

Figure 14. Cap-rock, above investigator, and as fall-rock on the right side of the photograph. Photograph by Norman Smyers, 05/30/2010.

Figure 15. Mike Bergstrom pointing to the location from which wall-rock sample HSC-100527-1 was collected. Photograph by Norman Smyers, 05/27/2010.

Conversely, the cave-forming wall-rock has little structural integrity and, remarkably, displays little to no stratification (Figure 15); therefore it tends to break down to individual sand-grains. Even on hand lens inspection I could find little to no evidence of stratification. On the whole, this wall-forming sandstone is so friable or easily crumbled that I could easily set loose a cascade of sand-grains by just dragging the sharp end of a rock hammer across its surface.

A sharp contact exists between the cap-rock and wall-rock units, a feature that, most likely, defines the existence of a stratigraphic break. In all aspects, it appears to be an unconformity or a surface that represents a period of erosion and/or non-deposition. Such surfaces separate younger from older strata. Absent good time-stratigraphic indicators, such as fossil remains and/or volcanic ash beds that can yield radiometric dates, it is difficulty to know what span of time this depositional gap might represent. In this regard, it is good to recall that a multitude of braided stream systems flowed across the Powder River Basin's alluvial plain during Fort Union times and that these stream and river ways were constantly changing course. Therefore, it is reasonable to assume that the time-gap represented by this unconformity at Horseshoe Cave could well be on the order of hundreds to thousands of years rather than millions of years. In addition, absent good time-stratigraphic control it is also difficult if not impossible to place this stratigraphic break at a definitive point in geologic time.

On all other accounts, both the cave forming wall and cap rock units are sandstones that appear to be remarkably similar in all respects. This raises a large question as to what might be the difference between the two so that one acts as a protective cover while the other, below it, can, seemingly, be easily "carved away" to form a large void?

An answer to this question is central to explaining one of the driving questions of the 2010 investigation, that is, what geologic processes led to the formation of the cave. The potential answer to this question will, perhaps, be found below in the sampling and analysis processes discussion.

Cave Floor. The materials comprising the surface of the cave floor differ from the walls and ceiling in the sense that they, for the most part, are comprised of loose and/or disaggregated or loose materials. Cave floor materials include grains of sand, silt, some clay, vegetative materials, animal bone and, as noted above, small to large pieces of wall and cap rock.

A large block of wall-rock is found along the south-wall and just inside the cave's opening (Figure 9). At some point in the past, an unknown individual or individuals chiseled a depression on the western side of this large block into which a horseshoe was laid (Figure 16). This horseshoe is the cave's signature feature and the source of its name. In addition to this large south-wall rock, smaller blocks of wall and cap rock litter other areas of the cave's interior.

Figure 16. Iconic horseshoe placed in fallen south-wall rock. Photograph by Norman Smyers, 06/03/2010.

The current condition of the cave's floor makes it difficult to determine its pre-disturbance character. In this regard, there are no known pictures of either the cave or its floor prior to the McLean's 1976 investigation. This is somewhat troubling because, in geoarchaeological terms, the pre-disturbance condition is important to assessing what geological forces may have played a role in the creation of the cave. Whatever conditions existed prior to 1976 was erased by McLean's investigation and by Fisher's investigations in 2008 and 2010. Therefore, any firm estimate as to its pre-disturbance character is highly speculative.

At the time of the field-investigation which fostered this report, the trench cut by McLean's 1976 investigation was very much in evidence as were the two units opened during Fisher's 2008 investigation. With respect to McLean's work, the trench backfill has either settled and/or blown out so that now some 10-20 cm (4-8 in.) of the trench wall is exposed (Figure 12). In addition, it appears to me that the slight berm or rise found on the right or north side of the cave's opening also appears to be evidence of McLean's investigation, very likely excavated material that was not returned to the excavation as backfill at close-out. The two shallow unit-sized depressions within the central cave area coincide with the location of Fisher's 2008 unit excavations.

Again, the pre-disturbance condition of the cave floor is important in identifying the geologic processes responsible for the formation of the cave. Namely, what were the geologic forces that acted together to create a simple overhang that now extends some 12 m (36 ft.) back into a sandstone unit to create a void large enough to be suitable for human use?

Fortunately, Michael Beckes (personal communication, January 2, 2011) was able to shed some light on this question. He recalls that when he first visited the cave in 1973 the floor of the cave was fairly level, more or less a sandy surface littered with vegetative debris and somewhat smooth or unbroken as it sloped upward toward the backend of the cave. He does not recall any berm or rise at the front of the cave nor any other noticeable depressions in the more central portion of the cave. He said what excited him the most about his discovery was that the floor appeared to be undisturbed and pristine in character. He said that, in his professional experience, it was unusual to find a cave of this size that had not been previously disturbed by archaeological investigators or pot-hunters.

Cave floor materials consist mainly of fine- to medium-grained sand and small and large pieces of ceiling and wall rock. These are, for the most part, materials freed from their host locations by both physical and chemical erosion and weathering. Commonly, both the physical and chemical weathering forces are assisted by surface moisture that first falls as precipitation and later, following cracks and fissures, moves downward to become lodged within the cracks as well as between individual sand grains. During the colder months of the year this moisture will freeze and expand to wedge-apart and fracture rocks and to separate individual sand grains from one another. In addition, precipitation generally contains some level of carbonic acid, an acid that can readily dissolve the calcite cement that commonly holds sand grains together.

Evidence of the role that water has played in the creation of the cave can be seen on its ceiling in the form of small gypsum speleothems (Figure 17). In a sense, these are miniature stalactites that form where gypsum laden ground water drips from the ceiling; but just as frequently the water can evaporate, thereby leaving behind small cylindrical deposits of

Figure 17. Gypsum speleothem on cave ceiling. Photograph by Norman Smyers, 05/31/2010.

white gypsum. These gypsum deposits document that surface moisture has gained entry into the cave through the many cracks and fissures in the cap-rock.

Cap and Wall Rock Features. The upper third of the cave walls, particularly the north wall, shows an array of large, 2-3 m (6-10ft.), wavy and flame-like patterns and large droplet-like features (Figure 18). The materials making up these patterns and features differ markedly from the weakly stratified, light-brown, even-grained sandstones of the lower two-thirds of the walls. These flame-like features are composed of coarser reddish-hue materials that, seemingly, flow across the (horizontal) structural grain of the cave walls in a wave-like fashion.

Figure 18. North wall seismite features. © photograph, S. Carpenter/IRP, 2010.

When I shared photographs of these features with Dr. Marc Hendrix, Professor of Geology in the University of Montana's Geoscience Department, he recognized them as being seismites or post-depositional structural features created by liquefaction of water-saturated sediments due to seismic (earthquake) sock-waves (Nichols 2009:275; Bartholomew et al. 2008:136-137; Ettensohn et al. 2002:182; Boggs 1995:72-74). Rossetti (1999:1068-1075) provides a thorough and informative treatment of seismites, a discussion that includes a host photographs and illustration; some of the features in his photographs and illustrations closely resemble features seen in the wall-rock of Horseshoe Cave, namely irregular convolute stratifications and ball-and-pillow structures.

A paper by Bartholomew et al. (2008:135-158) indicates that paleoseismite features are not an uncommon occurrence in the sediments of the Fort Union Formation. This paper by Bartholomew et al. (2008:135-158) provides a route of travel through the Bighorn Basin of Montana and Wyoming where multiple examples of seismite features can be found. The Big Horn Basin is located approximately 230 km (143 mi.) west of Horseshoe Cave. The features identified by Bartholomew et al. (2008:135-158) clearly demonstrate that Tongue River Member sediments were, indeed, subjected to seismic shock during Early Tertiary times. Therefore, it is quite reasonable to assume that the sediments at Horseshoe Cave were not immune to the effects of the same seismic shocks that affected time equivalent sediments in the Bighorn Basin.

Further support for the presence of paleoseismites features in Tongue River Member sediments can be found in Brown's (1993:L27) discussion of the depositional history of the Powder River Basin. She (Brown 1993:L27) described the disturbed sandstone facies (SL) strata as displaying "…convolute bedding, massive or structureless bedding, load casts and zones of inferred liquefaction…" which are features often developed when there has been rapid fluid escape from a water-saturated sediment due to "…seismic shaking or dewatering and compaction of underlying sediment."

It is worth noting that several features that are commonly associated with seismically induced changed to sedimentary rocks are noticeably absent at Horseshoe Cave, namely clastic dikes, sills, and diapirs. These are features created when seismic shock forces liquefied sand from one sedimentary unit into vertical cracks to form (sandstone) dikes, or between the bedding layers of another adjoining or nearby sedimentary unit to form horizontal (sandstone) sills, and perhaps elsewhere the fluid sand may rise up through the overlying sedimentary beds much like an atomic mushroom cloud to form a diapir (Nichols 2009:276-279; Rossetti 1999:1068-1075; Boggs 1995:150; Smyers and Peterson 1971:3201-3207). However, no such features were noted at Horseshoe Cave.

Their absence may be explained in two ways: first, when the wall-rock sediment was seismically shocked the unit was not covered by other sediment or, essentially, was open to the air, meaning there was no other unit above the wall-rock sediment into which portions of a fluid mass could be intruded; or second, there was another unit covering the wall-rock-unit that was subjected to intrusion but that unit, along with the evidence of seismically induced intrusion, was subsequently removed by erosion. This means that the current cap-rock unit would have later been laid down over the current and remaining wall-rock unit. Both scenarios are plausible, but the presence of the unconformable contact between these two units seems to favor the second scenario.

Structural Elements. The most noteworthy structural element that I observed at the cave is the deep cap-rock joint or fracture that, at least, on the surface runs the length of the cave and beyond its terminal or western end (Figure 19). As a surface feature, this fracture seems to be, more or less, aligned or positioned along the mid-line of the cave's long axis. With the exception of a

Figure 19. Surface expression of fracture above east-west axis of Horseshoe Cave. Photograph by Norman Smyers, 05/31/2010.

large hole or shaft near the cave's mid-point, this fracture within the cave is not all that noticeable. Nonetheless, I do believe that this and other fractures found within the cave have allowed water to enter the cave, water that has played a strong role in its creation and maintenance.

The magnitude and details of pointing or fracturing within the cave-host sandstones are somewhat difficult to determine given the limited vertical and surface exposures of both sandstone units. As can be seen in Figure 19 the surface of the cap-rock unit is, for the most part, obscured by a well developed soil and vegetative cover.

In an attempt to determine whether or not there was a local fracture pattern present, I used a Brunton pocket transit to measure the orientation of the surface expression of the large cave fracture, the bearing or trend of the long axis of Horseshoe Cave, as well as the bearing or trend of the long-axis of Finger cave and a small cave-like feature immediately east and across the drainage from Horseshoe Cave (Figure 20).

Figure 20. Small cave east of Horseshoe Cave. Note log-mold inside cave (black arrow). Photograph by Norman Smyers, 06/01/2010.

Finger cave is located about 10 m (33 ft.) to the south of Horseshoe Cave and along the same sandstone scarp that holds Horseshoe Cave. Essentially, its geologic characteristics are identical to those of Horseshoe Cave. Many consider it to be the sister cave to Horseshoe Cave. The small cave-like depression some 45 m (150 ft.) east of Horseshoe Cave appears also to be built into the same geologic unit.

I found the inside bearing of the long-axis of Horseshoe Cave to be N65°W and that of the surface fracture immediately above Horseshoe Cave to be N60°W. The long-axis of Finger cave was determined to be approximately N40°W and that of the small cave-like feature to be N58°W. The complementary orientation of these four measurements strongly suggests the existence of a preferred jointing pattern in the host sandstone in this portion of the North Fork of Jim Creek drainage.

An interesting side note to my inspection of the small cave-like feature was the discovery of a log-mold within it (Figure 20). This mold appears to represent the final evidence of a tree that had fallen into one of the many stream channels that crisscrossed the Early Tertiary alluvial plain of the Powder River Basin. As this tree began to decay, the products of decomposition began to accumulate on its outer surface where they acted as a glue or cement to which sand-grains became attached. Now exposed to the elements, all but the more durable remains of the tree have been removed thereby leaving behind a sandstone cast as the evidence of this long ago event. It is also interesting to note that, for some inexplicable reason, the orientation of the log-mold is essentially the same as that of the long direction of the cave.

According to Ayers (1986:1665), log-molds are not all that rare of an occurrence in Tongue River sediments, particularly in the northern reaches of the Powder River Basin or the area in which Horseshoe Cave is found. Ayers (1986:1665) further notes that these "…log-molds are associated with fine- to very-fine grained, moderately sorted sandstone…" which "…shows little evidence of sedimentary structures." In his (Ayers 1986:1665) description of sedimentary structures in, what he calls, the log-mold interval he mentions that unit characteristics "…change from large scale trough cross-stratification…at the bottom to small scale (ripple) cross-stratification at the top…" and that the "…upper 5-10 ft. is commonly well cemented by calcite and forms ridges at outcrop." In this regard, Ayer's (1986:1665) observations closely match many of the sedimentological characteristics that I found at Horseshoe Cave.

Lithologic Characteristics

A question central to any discussion regarding the formation of a cave is why one portion of a rock mass is more susceptible to removal than surrounding portions. In the case at hand, from even casual observation it is readily apparent that the sandstones into which the void, that is now called Horseshoe Cave, has been cut are far softer that the rock unit that forms the cover or ceiling for the cave. If it were otherwise given the physical setting of the Horseshoe Cave site, no cave could exist. That is, absent a strong and stable cover, soft sandstone would not have the integrity to form a cave. But it is also true that if the two sandstone units had been uniformly hard and without such structural breaches as cracks and fissures, weathering and erosion would have not been able to have established a foothold upon which to create a void.

This foregoing train of logic speaks directly to one of the central questions of this report, "What geologic process formed Horseshoe Cave?" In my opinion, the start to answering this question lies in lithologic characteristics of the rocks involved.

While it was initially believed that a field examination of the site and its lithology would be able to answer the question as to why the cave formed where it did, it soon became apparent that some laboratory analysis would be required to unlock the differences between the cave-forming rock unit and the over-lying cap rock unit. The following will detail how the field and laboratory sampling, examination and analysis processes were conducted to arrive at a response to the cave formation question.

Field Sampling and Analysis. Hand specimen analysis of the wall and cap rock units revealed no apparent differences between the cap-rock and the cave forming wall-rock. Because of this, I decided to collect samples for later laboratory study.

To meet this need, I collected four rock samples, two each from the wall-rock and cap-rock units. Each sample measured roughly 12 x 3 x 3 cm (5 x 3x 3 in.) in size and weighed approximately 800-1,000 gm (2 lbs.). The two cave forming wall-rock samples, labeled HSC-100527-1 and HSC-100531-3, were collected from the south wall of Horseshoe Cave. HSC-100527-1 was collected from just within the south-side entry to the cave and at the east end of a large block of fallen wall-rock, the rock that contains the horseshoe (Figure 15). HSC-100531-3 was collected at a point about 109 cm (43 in.) in from the cave's opening and about 24 cm (9.5 in.) above the cave floor.

The cap-rock samples, HSC-100531-1 and HSC-100531-2, were both taken along the north edge of the cave's opening. They were taken in close proximity to one another because of a concern that sampling toward the center of the cave opening might cause stability problems that could represent a safety hazard to investigators. Thus the two samples were taken in an area where little future human activity was anticipated.

In addition to the rock samples, I also collected one sample from a pile of screened material that came out of Unit 3. My intent in this case was to see if it at all differed from either the cap-rock and/or wall-rock specimens. This sample, HSC-S-100601-01, of came from near the 1.1 m (43 in.) level of Unit 3. This unit was located in the back-half of the cave or approximately 5 m (16 ft.) in from the cave (drip-line) opening. This weighed about 300-400 gm (10-14 oz.).

For comparison purposes, one rock sample (HSC-100531-04) was collected from a set of hoodoo structures that lay approximately l.6 km (1 mi.) to the west of Horseshoe Cave (Figure 7). The sampled location was several feet above the southeast facing basal edge of the hoodoo structure and from a rock mass that looked very similar to the cave-forming wall-rock of Horseshoe Cave.

Laboratory Processing and Analysis. A hand lens and binocular microscope examination of all five samples collected at Horseshoe Cave did not reveal any notable differences between any of the sampled materials (Table 2).

Without exception, the average grain-size for all of the samples collected at Horseshoe Cave ranged between 0.25 and 0.10 mm, fine to very-fine sand. The shape of all grains was angular to sub-angular. Quartz was the dominant component (60-85%), followed by feldspar (5-15%), with mafic minerals averaging 5-10% of the total mass. On the whole, these findings compare favorably with the reported results of other Powder River Basin investigators such as Ayers (1986:1665-1670), Merin and Lindholm (1986:128-130), and Brown (1993:L25-L29).

The Hoodoo sample differed from the Horseshoe Cave samples in two respects in that its average grain-size range was a bit larger at 0.25-0.50 mm, medium to fine sand, and its percentage composition of mafic minerals was slightly greater than that of feldspar, 10-15% as opposed to less than 10% for feldspar.

Because of this lack of apparent physical and compositional differences between Horseshoe Cave samples, it was decided that two samples each of the wall- and cap-rock should be subjected to thin-section analysis. Portions of these four rock samples were sent to *Spectrum Petrographics* for thin-sectioning and staining.

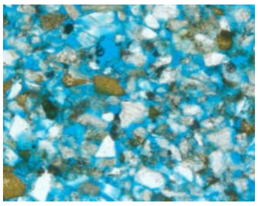
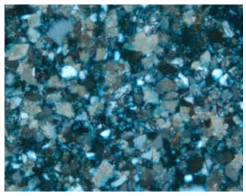
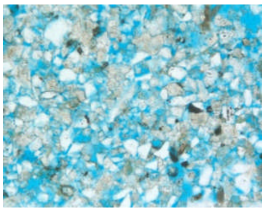
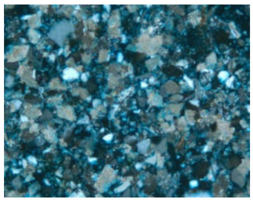
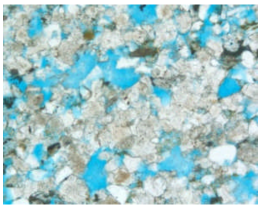
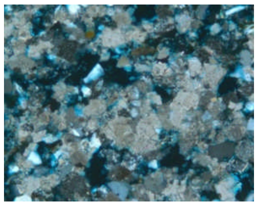
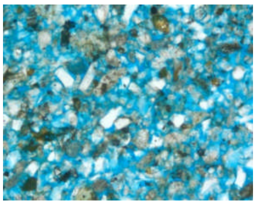
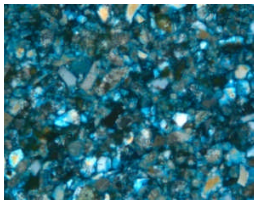
Table 2. Rock and Sieve Sample Examination Results

Sample Number	Source	Average Grain Size (mm)	Shape	Composition	Remarks
HSC-100527-1	Wall-rock	0.25-0.20 Fine to Very Fine sand	Angular to Sub-Angular	>60% Quartz 10-15% Feldspar 5-10% Mafics	Mafics: Mix of biotite, muscovite, and apatite. Thin-section: 5-10% interstitial calcite cement
HSC-100531-1	Cap-rock	0.25-0.16 Fine sand	Angular to Sub-Angular	>80% Quartz <10% Feldspar <10% Mafics	Thin-section: 20-30% interstitial calcite cement
HSC-100531-2	Cap-rock	0.50-0.25 Medium to Fine sand	Angular to Sub-Angular	>75% Quartz 10-15% Feldspar 5-10% Mafics	Mafics: Dominated by biotite. Thin-section: 40-50% interstitial calcite cement
HSC-100531-3	Wall-rock	0.25-0.10 Fine to Very Fine sand	Angular to Sub-Angular	>85% Quartz 5-10% Mafics <5% Feldspar	Mafics: Biotite, muscovite, and apatite. Thin-section: <10% interstitial calcite cement
HSC-100531-4	Hoodoo	0.50-0.25 Medium to Fine sand	Angular to Sub-Angular	>70% Quartz 20% Mafics <10% Feldspar	Mafics: Apatite, augite, and biotite.
HSC-100601-1	Unit 3 Screened	<0.25 Fine to Very Fine sand	Angular to Sub-Angular	>85% Quartz 10-15% Mafics <10% Feldspar	Mafics: Biotite, apatite.

When these four thin-sections were examined under a microscope using polarized light, the difference between the cap-rock and wall-rock samples was quite dramatic--the interstitial fill of the cap-rock was 20-50% calcite as opposed to 10% or less for the wall-rock. Thus the thin-section analysis verified what I had suspected--that the higher degree of cap-rock induration or hardness was due to a greater percentage of calcite cementation. The results of the petrographic microscopic examination can be found below in Table 3.

The results of the thin-section analysis instantly raised the question as to why one sandstone rock unit would have more calcite cement than another, particularly when the two units are immediately adjacent to one another. Maybe the answer to this question lies in the

Table 3. Photomicrographs of wall and cap rock sandstone samples taken from Horseshoe Cave. Taken with *Leica* DMLP petrographic microscope at 25X.

Sample	**White Light**	**Polarized Light**
HSC-100527-1 Wall-rock		
HSC-100531-1 Cap-rock		
HSC-100531-2 Cap-rock		
HSC-100531-3 Wall-rock		

**When given a blue-stain and under polarized light calcite appears as medium gray rectangular masses.*

presence of the apparent unconformity that separates the two units. The presence of this unconformity was discussed above in *Form and Content: Ceiling and Walls*.

Over time, the conditions under which the subject sandstones were deposited can vary significantly. With respect to the case at hand, these variations can as well extend to the amount of calcite cement available during deposition. In this regard, and as mentioned above, Ayers (1986:1665) reported that the upper 1.3-3 m (5-10 ft.) of his (Tongue River Member) Framework Facies "…is commonly well cemented by calcite…" Merin and Lindholm (1986:128-130) offer some explanation as to fluid makeup of sediments may have changed over time when they demonstrated that as the rivers cut deeper into the flanks of the mountains surrounding the Powder River Basin they encountered calcite bearing rocks of Paleozoic age. These calcite rich particles joined the suite of materials flowing into the Basin, and, in so doing, changed both the chemistry of the transporting water and compositional makeup of the sediments being deposited in the Basin.

Regardless of its source, the degree of calcite concentration accounts for the vast difference in induration or hardness between the cave-forming wall-rock and the overlying cap-rock unit, a difference vital to the formation and continuance of a (sandstone) cave feature.

EXCAVATION UNITS

As discussed previously, the Horseshoe Cave site has been subjected to four formal archaeological investigations, each involving excavations. McLean (1976) conducted the first excavations at the site in 1976. Fisher followed with new excavations in 2008 and 2010. The findings of the 2008 investigation were discussed in an unpublished paper by Fisher (2010a), a paper that also provides some information and thoughts regarding Mclean's 1976 work at the site.

Fisher's latest investigation at the site was in 2011. In effect, this work can be considered an extension of his 2008 excavations in that it involved the removal of backfill from Unit 2 and the taking of a column sample from the southwest corner of the unit.

In the discussion to follow, I will begin with my analysis of McLean's 1976 investigation. I will then follow with what I have learned from Fisher's 2008 work and my involvement with the 2011 inquiry. I will then conclude with a discussion regarding the excavations of 2010 and what, so far, have been learned from the three units opened during that investigation.

I would emphasize that the following comments and observations are based on my review and interpretation of the information previously documented by McLean (1976), Fisher (2010a) and, as well, from my participation in Fisher's 2010 and 2011 investigations. The focus of this review will be the character of the stratification, composition and structure of the sediments and, most importantly, the existence of any evidence of the geological and sedimentological processes that might be responsible for the morphology of the cave and the deposition of the materials that now form its floor.

In addition, since the impetus for this report is archaeological in nature, my review will take notice of those features associated with the form and stratigraphy of the cave that may have anthropogenic origins.

McLean 1976

In 1976 McLean opened four 1.5 x 1.5 m (5 x 5 ft.) excavation units. These units were arranged in a contiguous fashion to form a trench 1.5 x 6.1 m (5 x 20 ft.) long (see Figures 9, 11 and 12). This trench cut through stratified deposits to a maximum depth of 3.84 m (12.6 ft.) below the ground-surface (Fisher 2010a:1; McLean 1976:76-87)..

Features. Cultural features and materials encountered in the trench included the remains of seven firehearths and, often in association with the hearths, stone and bone artifacts (Table 4)

Table 4. Cultural features encountered by McLean's 1976 Horseshoe Cave excavation**.**

Feature	Depth (cm)	Remarks
Feature 1-Firehearth.	33-38	Diameter 79 cm; 5 cm thick layer of charcoal & (red) discolored soil; fire-cracked rock; associated bone awl at 30.5 cm (see Table 5).
Feature 2-Circular firehearth.	46-51	Diameter 48 cm; charcoal & fire-stained soil; associated porcellanite flakes at depth of 46-53 cm.
Feature 3-Firehearth.	97-102	Partially exposed; maybe 46 cm across; fire-stained soils; sandstone slabs on either side of hearth; fragments of burnt bone & porcellanite flakes.
Feature 4-Charcoal & fire-stained soil.	109-132	Partial exposure of firehearth w/74 cm dimension along N-S axis; basin shape; 23 cm thickness; fire-cracked rock line charcoal deposit; judged to be roasting pit; associated artifacts include porcellanite flakes, burn bone, canine mandible.
Feature 5-Cultural materials and associated firehearth.	157-165	Numerous flakes, biface blade fragments, projectile point fragments, complete side-notched blade; bison mandible, ribs & vertebrate.
Feature 6-Firehearth.	244 cm	Charcoal; discolored soil; fire-cracked rock; bone fragments; porcellanite flakes.
Feature 7-Firehearth.	292-300 cm	Partially exposed; no artifacts.

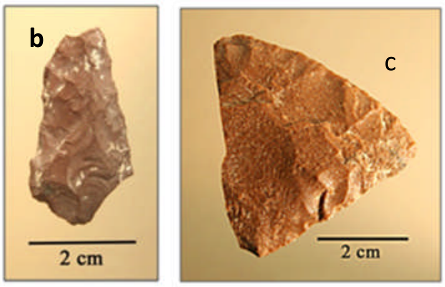
Artifacts. McLean (1976:86-87) recovered five bone and lithic artifacts whose size and form suggest their past intended use. One, Artifact a, is a clearly a bone awl. The two fragmented blades, Artifacts b and c, represent (broken) projectile points, scrapers, or knife blades or, possibly lithics that severed two or more of these uses before being either lost or discarded.

Artifact d, on the other hand, is clearly a projectile point; one that, in my opinion, has the size and form characteristic of points associated with the Besant cultural traditions (Late Plains Archaic-Late Prehistoric) (Frison 1991:105-106 and 199-200).

Table 5. Horseshoe Cave artifacts recovered by McLean in 1976. Photographs used by courtesy of Jack Fisher.

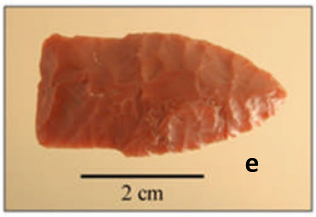
Artifact a. Bone awl found in association with Feature 1 and at a depth of 30.5 cm.

Artifacts b and c. Fragmented blades found in association with Feature 5.



Artifact d. Complete blade found in association with Feature 5.

Artifact e. Re-worked Scottsbluff projectile point found at depth of 195 cm.



Artifact e has characteristics that could be attributed to both the Late Plains Prehistoric and Early Plains Archaic cultural traditions (Frison 1991:24). McLean (976:85-86) considered this point to be a re-worked Scottsbluff projectile point. This point, with questionable stratigraphic integrity, was recovered from a depth of 1.95 m (77 in.) (Fisher 2010a:2; McLean 1976:85-86). Using Frison's (1991:24-36) cultural chronologies for the Northern Plains, a Scottsbluff point would be late Paleoindian in age or 8,500-9,400 B.P. On the other hand, this one was one of three projectile points that received close scrutiny by Bonnichsen and Keyser (1982:137) in their review as to whether or not projectile points of the Cody Culture can "…fit into established typological schemes." Bonnichsen and Keyser (1982:137-143) concluded that this projectile point was nothing more than a "…resharpened Cody Complex point," an opinion based on the "…presence of a small spur reworked at the intersection of the base and lateral edge of the stem…," a feature that"…has been observed on other Cody Complex points." In is important to note that both Cody Complex and Scottsbluff cultural traditions are of late Paleoindian, essentially then, cultural contemporaries. Therefore, regardless of its cultural affiliation, it remains a projectile a point that is some 8,000-9,400 years old.

Faunal Remains. Animal bones recovered by McLean's (Fisher 2010a:2; 1976:100) excavation include coyote (*Canis latrans*), modern horse (*Equus caballus*), domestic cattle (*Bos taurus*), modern bison (*Bison bison*), bighorn sheep (*Ovis canadensis*), deer (*Odocoileus sp.*), hare (*Lepus sp*.), pygmy rabbit (*Sylvilagus sp.*), wood rat (*Neotoma cinerea*), deer mouse (*Peromyscus maniculatus*), and meadow vole (*Microtus pennsylvanicus*).

Radiometric Dates. For this investigation, the most useful information provided by McLean (1976:73-87) are two radiocarbon dates that were obtained from materials collected at depths of approximately 1 m (39 in.) and 1.6 m (63 in.) respectively. The first date was obtained from the

Feature 3 charcoal deposit and it yielded a Late Prehistoric radiocarbon date of 597 ±100 years before present (B.P.). The second date was provide by material collected from a bison mandible found in association with Feature 5, it yield a Late Plains Archaic date of 2163 ± 80 years B.P.

Sedimentation Rate. Using this above data I calculated an average annual rate of sedimentation for the area where these sites were recorded. To do so, I took the vertical stratigraphic distance between the two locations where the carbon samples for the dates were obtained and divided that distance by the difference in years between the two samples. The result of this simple approach was an average annual sedimentation rate of 0.5 mm (0.2 in.) per year. However, sandstone caves and rockshelters do not have the long-term consistency of deposition that is commonly associated with limestone caves. Therefore, the resulting number needs to be accepted with a degree of caution.

An explanation of this difference between sandstone and limestone caves is due to several differences in structure and composition. To begin with, both materially and structurally sandstone is not as sound as limestone. Sandstone, for example, will break-down in a grain-by-grain fashion on an almost annual basis. Limestone grains, on the other hand, are tightly bonded together and the mass of limestone is generally reduced by dissolution, a process requiring moisture. In arid regions, dissolution of limestone is a very long and extended process. This lack of tight grain-to-grain bonding makes sandstone more susceptible to disintegration and fracturing. This breakdown will then result in rock falls that, generally, are more frequent in sandstone as opposed to the frequency associated with limestone caves (Rapp and Hill 2006:81-86; Goldberg and Macphail 2006:169-187; Waters 1992: 240-247).

Therefore, caution should always be exercised when attempting to estimate an average annual sedimentation figure for a sandstone cave, particularly when there are only a few data points to work from, which is the case here.

Fisher 2008

In 2008 Fisher (2010a:9) opened two contiguous units along the northern half of the cave. The measured size of each of these two units was 2 x 2 m (6.5 x 6.5 ft.) in size, but the excavated portion of each was approximately 2 x 1.5 m (6.5 x 5 ft.) (Figure 9). This produced an east-west oriented trench with a length of about 3.8 m (12.5 ft.). The western most of these two units was designated Unit 1 and the eastern most Unit 2.

Unit 1. The maximum depth reached by Unit 1 was 180 cm (71 in.) below the ground surface. Then entire floor of the unit in this area of the cave was covered by soft, light-colored sandstone similar to that forming the walls of the cave. The excavation stopped or "bottomed" when it reached a, somewhat, durable light colored dense sandstone. The excavation and screening of the removed materials yielded 4 porcellanite flakes and 496 bones specimens (Fisher 2010a:10-12).

Fisher (2010a:9-12) posits the termination level of the excavation could represent "…either a large slab of soft sandstone that broke off the north wall…or the bedrock floor of the rockshelter." After reviewing his 2008 field notes and profiles, I concur that both are valid assumptions; both, however, hypotheses difficult to verify without further excavation or through the use of ground-penetrating radar (GPR) (see below, *Suggestions For Further Research*).

Indeed, this soft sandstone could be either a large slab or the bedrock floor of the cave. However, if this soft sandstone represents the upper surface of a block or slab of sandstone that has fallen off the north wall, then there exists a possibility cultural materials could lie below it.

On the other hand, if the sandstone represents the bedrock floor of the rockshelter, then it is clear that no additional artifactual material will be found by deeper digging. More importantly, it demonstrates that the cave's "wall forming" sandstone is thicker than what can be seen at the floor level of the cave and along the scarp into which the cave has been carved. In that regard, the vegetative cover in front of the cave and for some distance around its opening clearly does not provide a view that allows one to accurately assign an overall thickness for this unit. That said, I believe that the wall forming unit is at least three to five feet thicker than what is seen in the immediate vicinity of the cave.

Unit 2. Unit 2 reached a maximum depth of about 135 cm (53 in.) below ground surface. Even though it did not reach quite as deep as Unit 1, the volume and quality of information recovered from Unit 2 was noticeably more robust (Fisher 2010a:10-11).

Features. Three prominent hearth features can be seen in the profile of the south wall of Unit 2 at

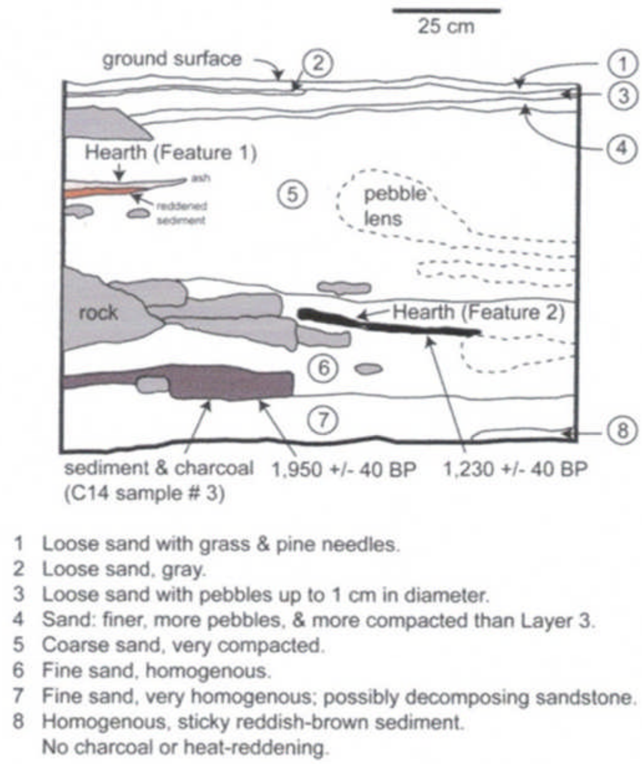
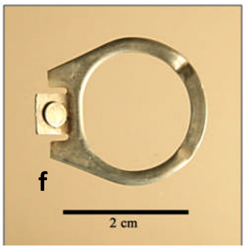


Figure 21. South wall profile of Unit 2. From Fisher 2010a:Figure 4.

depths of 35-40 cm, 80-90 cm and 115 cm (Figure 21). Three distinct hearth features can also be seen in the east wall profile (Appendix A). While some charcoal appears in the north wall profile, it contains no overt evidence of hearth features. Without question the bulk of cultural evidence is found along the south and east margins of the unit.

Artifacts. This unit yielded a variety of materials from contemporary aluminum waste, to animal bones, porcellanite flakes, and the base of a porcellanite projectile point tentatively identified by Fisher (2010a:10) as Besant (Late Plains Archaic--early Late Prehistoric).(Table 6).

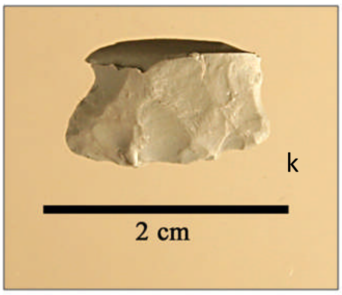
Table 6. Horseshoe Cave Unit 2 artifacts recovered by Fisher in 2008. Photographs used by courtesy of Jack Fisher.



Artifact f. Aluminum can pop-top tab recovered from the upper layers of Unit 2.

Artifacts g-i. Porcellanite flakes found at about 120 cm of depth.

Artifact k. Porcellanite projectile base tentatively identified as Besant found at 120 cm of depth.



Radiometric Dates. Photographs and a profile of Unit 2 (Figure 21) provide some important information regarding the sedimentological past of this area of the cave. For example, one of the charcoal samples came from a depth of approximately 90 cm (35 in.) and yielded a radiocarbon date of 1,230 ± 40 years B.P. The other charcoal sample was collected at a depth of about 115 cm (45 in.) and yielded a Late Plains Archaic radiocarbon date of 1,950 ± 40 years B.P. (Fisher 2010a:11).

Sedimentation Rate. Using the same approach used for McLean's trench, I calculated the average annual rate of sedimentation at this location to be about 0.35 mm (0.02 in.) per year.

Weathering, Erosion and the Sedimentary Process. While there were several large pieces of fallen roof or ceiling rock either encountered or removed during the excavation, it appears that the greater volume of fill is the result of a slow grain-by-grain disintegration of the surrounding sandstone ceiling and wall rock units.

Three pebble lenses are found in the west half of the south wall profile, essentially the same area in which column samples were taken during the 2011 investigation. These lenses are noticeably distinct from the other sediments as a good proportion of their content is made up of small pebbles, an attribute that gives them a coarse appearance. Two of these are in the upper two-thirds of the profile and the other in the middle portion of the lower third. The upper most has a (reclined) balloon shape and the one below is more lenticular in form. The lower pebble zone has a less pronounced balloon shape than does the highest one. The column samples taken in 2011 cut through portions of all three lenses (see *Fisher 2011* below).

In closely examining both the south-wall photographs and profile, I see no overt evidence of a rapid or vigorous movement and deposition of materials by water and or wind; in other words, evidence such as recognizable rivulet channels and cross-bedding that would indicate the past movement of water and/or the influx of wind-blown materials. In fact, aside from the large pieces of fallen rock, I see only subtle stratigraphic separation between the materials making up the walls of the excavation unit. The sieve analysis, however, revealed a somewhat more complex sedimentological history. For one, the presence of the three pebble lenses alone indicate that some force, more than likely water, moved the materials into and across the cave floor at times.

One of the more interesting aspects of this south wall profile is the apparent thickening of some definable units as one follows them from west to east or from the back of the cave to its opening. This feature is akin to water moving sediments downhill to their point of deposition in a basin. In this case, the back end of the cave represents highland areas and the front portion of the cave a deeper sedimentary basin. In the example of mountains and basins, one would expect the weathered and eroded materials that cover the highlands to be thinner than the sedimentary mass laid down in a wedge-like fashion in the basin. Applying this concept to Horseshoe Cave, Unit 1 would represent the highlands and the (sedimentary) basin would be the eastern half of Unit 2.

Finally, if there is any distinction between the layered portions of the cave-floor sediments it would be based more on color than on definable stratigraphic breaks and /or changes in the size of lithologic materials. It also appears that some difference in color may, in fact, have been induced by past human disturbance of the cave-floor as well as by natural geologic processes and events.

Units 1 and 2 Considered Together. Fisher (2010a:12) noted that "In Unit 1 the bones and lithics are rather evenly distributed among the most of the excavation levels …" whereas in "…Unit 2…" they are "…most abundant …in the lowermost excavation levels," an apparent pattern of occupation for which he could offer no explanation. Fisher (2010a:12) posits this distribution could have resulted from human behaviors, namely differential use of space within the cave by the people who used Horseshoe Cave as much if not more than the activities of rodents moving objects around on the floor of the cave.

This idea of differential use of space is bolstered by a close examination of the profiles of Units 1 and 2 (Appendix A) that reveals the basement floor slopes downward from west to east (toward the cave's opening) as well as downward from the north wall to the south wall. Without question, this geometric configuration provides for greater head room along the southern front edge of the cave, a dimensional aspect that allows for more comfortable entry and occupational use of the cave. This is the case today and it surely was in the past as well.

The west to east slope of the floor is interrupted by large amounts of downfall near the cave's (current) opening and along its south wall are rock pedestals that could either be large blocks of fallen wall rock, the bases of which are either too deep to define or represent high points in the bedrock floor of the cave. An added complication to answering this question is that the rock making up the (base rock) floor of the cave and its walls are one and the same. A definitive answer to this question would require further excavation and/or the use of the Ground-Penetrating-Radar (GPR).

Near the opening edge of the cave, the sedimentary sequence includes a large volume of roof rock. When compared to other areas within Unit 2 its eastern portion contains a greater density of cultural features and materials, e.g. hearth features, charcoal, porcellanite flakes, a porcellanite core, and animal bones. This raises several questions about the potential positioning of human activities. Did human activities occur here due to an increase in cave height in this area as opposed to further back in the cave; or because of the availability of large stones and rocks that could be used as "furniture;" or does it represent a location better suited for the drafting out of fire smoke? Regardless, the greater density of cultural materials in this area strongly suggests that this area was one of the more habitable locations within the cave at the time these materials became incorporated into the cave's stratigraphic record.

There are several features or elements seen in the profiles of both units that suspiciously look like animal burrows and living spaces. The west wall profile of Unit 1 contains Feature 12, a feature that is described as a lens of "grey powdery loam," the same description given to Feature 13. Feature 8 in the unit's north wall (profile) is another a structure that can be easily interpreted as a rodent living space, one with two access routes to its left (west) and right (east).

Similar features or structures can be seen in the south wall profile of Unit 2 as well, namely the pebble lenses. Bill Eckerle (personal communication 2012) suggested these large balloon-like structures could be the result of burrowing rodents in short, access routes and living chambers. However, since the referenced view is planar and not three-dimensional, it is difficult to know whether or not similar "access routes" exist to the south of the profile's face or toward the south wall of the cave, information that might support a rodent burrowing theory.

There are several mammalian preference factors that cast doubt on these features being animal structures. Currently, there are only two burrowing rodent species present in the Northern Plains that are sometimes seen at the entrances to cave, mines (adits), and rockshelters, these are the thirteen-lined ground squirrel (*Citellus tridceemlineatus*) and the yellowbelly marmot (*Marmota caligata*) (Collins 1959:278-284). However, according to USDA-Forest Service Wildlife Biologist Mike Hillis (personal communication 2012), the thirteen-lined ground squirrel prefers an open site for burrowing, one that offers a 360° view of the surrounding terrain. Such a situation that might be available in a more open rockshelter, but not one normally found within the interior of a cave. While the yellowbelly marmot might be comfortable with taking up residence at the entrance to a cave, the features or geologic structures mentioned above appear to be much too small for a full grown marmot to have produced them. In my opinion, if the subject area was in a more open setting, a number of rodent species could be considered potential candidates for the creation of these features, but not here. More will be said about the pebble lenses below in the discussion dealing with the 2011 field work.

Finally, animal species identified from the bones recovered from Units 1 and 2 include cottontail rabbit (*Sylvilagus sp*.), domestic cattle (*Bos taurus*), bison (*Bison bison*), deer (*Odocoileus sp*.), fox-sized canid (cf. *Vulpes vulpes*) and coyote-sized canid (cf. *Canis latrans*) (Fisher 2010a:12).

Fisher 2011

Because of adverse weather conditions at the time of the scheduled field investigation, the focus of the proposed 2011 activities was narrowed down to examining the cave's climatic past. This task was to be accomplished through a close order examination of a stratigraphic sequence of cave sediments. There was no attempt to search for and or collect other materials such as artifacts or faunal materials.

Figure 22. View of the southwest corner of Unit 2 where the two 2011 column samples were taken. Photograph by Bill Eckerle, 05/25/2011.

As will be discussed in more detail below, the research approach is to compare the percentage differences of the various size fractions making up the sediments, their compositional components (e.g. mineral grains, rock fragments, artifactual materials, etc.), and any other characteristics that might provide clues to the climatic conditions at the time of their deposition.

An area in the southwestern corner of 2008's Unit 2 was selected from which to take samples. In this area two closely spaced and parallel columns with a bulk wall in between were laid out. From the ground surface to its base, each column was approximately 135 cm (53 in.) in length and about 12 cm (5 in.) wide; the bulk wall was approximately 12 cm (5 inch) in width (Figure 22). The column on the left-hand side was labeled Column A and that on the right-hand side Column B.

A sample was taken from each 5 cm (2 in.) interval along each column's length. The depth of each sample extended approximately 10 to 12 cm (4-5 in.) into the wall of the unit. As much as possible, each sample consisted of the sediment within each 5 cm interval. For later analysis, Bill Eckerle took possession of the Column A samples and I took possession of the Column B samples. The Column A samples numbered 27 while the Column B sample series consisted of 28 separate samples. This difference was because the lithology of one interval (-45 to -50) of Column B was broken between a pebble lens and a non-pebble lens. Thus, the decision made in the field was to collect each lithology separately.

Once in the laboratory, the investigative process continued by first determining the wet and dry *Munsell* colors of each interval, its pH. Following these two initial actions, the samples were then screened and the weight of each fraction measured.

The results of the sieve and microscope analysis for each sample interval can be found in Appendix B. However, in summary, the samples range in weight from 392 to 1083 gm (14-38 oz.) with an average weight of about 699 gm (24 oz.); have a pH range of 8.0 to 8.6 with a mean of 8.3, thus somewhat moderately alkaline (Calcium carbonate); display a positive skew of 0.1, which means, overall, the coarser admixtures slightly exceed the fine (Pettijohn 1957:37; Spatz 2005:48-51 and 75); and have a calculated range of sorting of between 1.4 to 10.9 with an average sorting of 3.1.

Using the visual standards employed by both Marshak (2001:181) and Compton (1962:214) the sediments can easily be considered to be “moderately” to “poorly” sorted. When considering the potential variety of sources for the floor sediments, this is not surprising as the sedimentary sequence present in the cave consists of individual sand-grains, large slabs and small pieces of rock coming from both the ceiling and walls of the cave. In addition, the sedimentary sequence also consists of a smaller contribution of rock and fine-grained sediments carried or blown into the cave by both wind and water.

As mentioned above, one characteristic that is of particular interest here is the size distribution of the various size fractions, that is coarse vs. fine. Another characteristic of interest is the presence or absence of grain frosting. The implications regarding this characteristic will be discussed in detail below.

With respect to size-fractions, it is held by many (Goldberg and Macphail 2006:175-177; Rapp and Hill 2006:81-85; Waters 1992:241-244) that sedimentation within caves is often a closed system, that is, it receives only limited input from outside the cave. When it can be shown that water is a minor sediment contributor to a cave, the importance of wind needs to be considered. That said, the potential that some materials may have biogenic and/or anthropogenic origins should not be overlooked (Waters 1992:243-244).

Furthermore, it has been demonstrated that increases in the proportion of fine-grained to coarse grained materials may well indicate dryer and arid conditions, a period where the land is more exposed and open to wind erosion and, by extension, the deposition of fine grained sediments within cave environments (Huckleberry and Fadem 2007:24-30; Finley 2008:27, 236-239 and 288).

To support such a contention, researchers often look for grain frosting. Marshak (2001:191), Kibler (1998:183), Pettijohn (1957:69-70) contend that grain frosting is an indication of aeolian transport. Marshak (2001:191) describes frosting as a process where "…in wind storms, the grains become frosted (in the same way that rubbing glass with sandpaper makes the glass frosted) and well rounded."

Therefore, if frosted grains are noted in the sieved size fraction but not so in the grains of the rocks that make up the cave environment, they had to have come from a source outside the cave's environment—with wind being the most likely transport agent. Grain frosting is important to distinguishing endogenous from exogenous sediments, those that came from the material hosting the cave versus those sediments that came from outside that cave's immediate environment. The volumetric difference between the two becomes an important tool in determining what environmental conditions existed at the time the sediments were deposited within the cave.

The Holocene environment of the Northern Plains, particularly north-central Wyoming and southeastern Montana has been marked by periods of exceptional aridity with extensive sand dune development and fine-grained sedimentation in cave environments (Finley 2008:27 and 51; Eckerle 1997:142-149; Larson 1997:117-118). Even today, as noted above, the present climate of the area is semi-arid. Here, any decrease in annual precipitation will bring on a corresponding loss of vegetative cover. With the land surface laid bare strong winds are then able to erode and transport fine-grained rock materials.

Eolian or wind-driven transport can move larger than silt-sized grains by a process known as saltation. When saltation occurs, fine to medium-sized sand grains move downwind by hopping or skipping along the ground. Small size fractions--silt and clay sized materials--can be picked up by the wind and transported in suspension and carried long distances before settling back down to earth (Waters 1992:186). This means that the sand sized found in the stratigraphic column at Horseshoe Cave, especially the larger than very-fine sand has, most likely, been derived locally. The source of very-fine sand, silt and clay sized fractions could be local but it could, as well, have been derived from more distant sources.

It is also important to remember in this discussion that the average grain-size of both the cap and wall rocks is 0.10 to 0.25 mm (very fine to fine sand). Therefore, absent grain frosting it may well be difficult to separate the contribution of wind blown sand from that of the surrounding sandstone rocks. On the other hand, the silt and clay content of the surrounding sandstone rocks was very minimal, if not totally absent.

With these parameters in mind, an attempt to identify dry periods was made by graphing the weight percent of each of the sieved size fractions (Figure 23). The horizontal axis of the resulting graph denotes the relative weight-percent of each size-fraction while the vertical axis has two measures, one the depth below surface-level and the other the distance of each sample interval above or below the site's established zero datum level.

Using this format, dry periods should, therefore, be identified by a marked increase in the fine-fractions; and, in fact, the resulting graph displays four strong if not clear-cut markers and one of moderate strength. The four strong markers occur below the surface at depths of 10-15, 35-45, 75-85 and 125-130 cm. Interestingly enough, unlike the other strong markers, the 75-85 cm interval occurs without a corresponding decrease in the coarser fractions. Moderate markers occur at depths of 20-25, 60-65, and 100-100 cm.

Unfortunately, due to the lack of temporal control it is not possible to correlate, with any reliability, any of these markers with several of the climatic chronologies that currently exist. Eckerle (1997:143) provides a Late Pleistocene-Recent paleoenvironmental and archaeological correlation chart for the Wyoming Basin, an area that is inclusive of the Powder River Basin. However, its temporal reach is much too coarse for the 2,000 years or so represented by the sedimentary sequence sampled at Horseshoe Cave. Finley (2008:253) offers a comparison diagram that correlates the rockshelter formation process with inferred environmental and climatic interpretations, one that offers some fine scale chronologies for the past 800 years (Figure 24). While it would be tempting to correlate some of his fine scale events with the

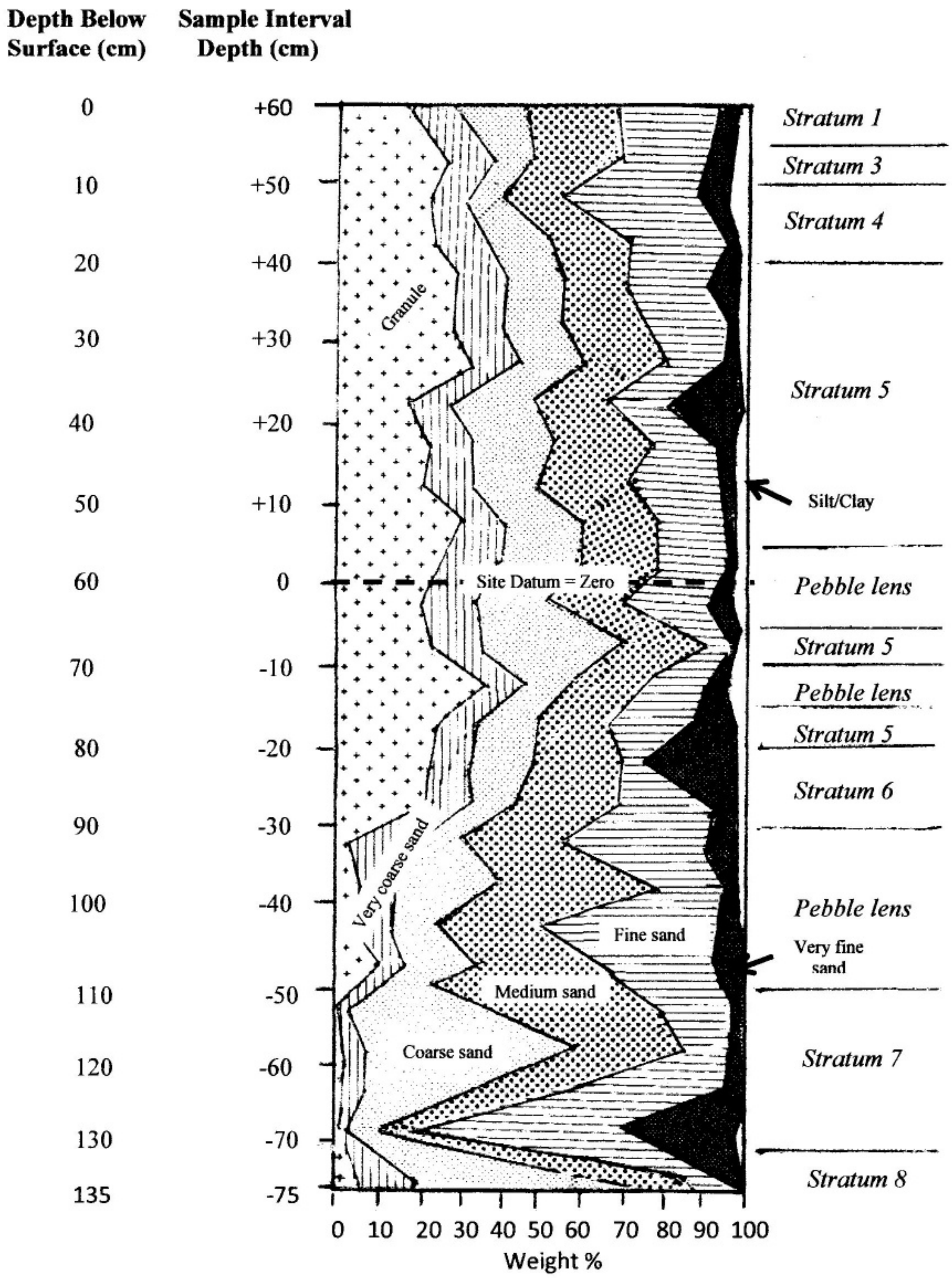


Figure 23. Graphical representation of sieve data found in Appendix B.

fine-scale events with the results seen in Figure 23, the lack of corresponding fine-scale temporal control at Horseshoe Cave makes such a venture quite risky and, essentially, unsupportable.

I made a visual (qualitative), not a quantitative or statistical, review of the degree of frosting within each of the fine-grained fractions of each sample interval. What I discovered was that frosted quartz grains can be found in some of the intervals not identified with the zones that have a potential tie to dry and/or arid periods. However, there appears to be a definite increase in the frequency of frosted grains in those intervals identified as potential dry and/or arid times. For sure, all of the potential dry and arid intervals had frosted grains whereas, elsewhere in the column, some intervals lacked frosted grains altogether.

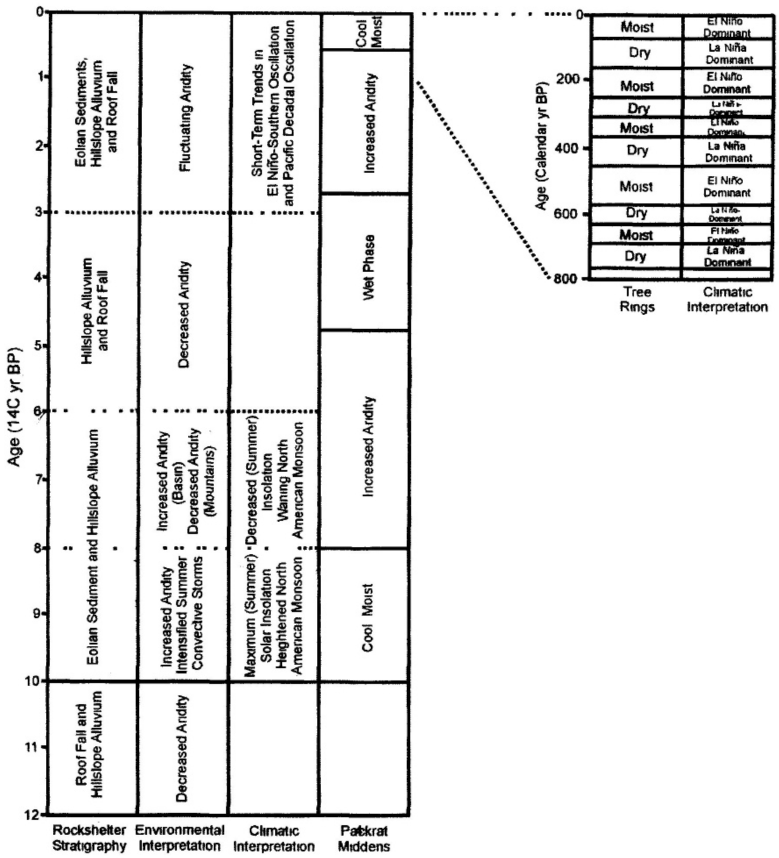


Figure 24. Pleistocene to Holocene climate changes. From Finely 2008:Figure 8.2.

The presence of frosted grains in a “non-dry” interval can be explained in a number of ways. One, they could represent the redistribution of materials from above or below. Redistribution could well be due to anthropogenic or biogenic disturbances such as the movement of humans and animals within cave and/or the excavation of cave floor materials by both humans and animals. Another potential explanation is that there were occasional dust storms during the wetter periods. But, again, the frequency of frosted grains appears to be higher in the four “dry/arid” intervals than in the other intervals.

Unfortunately, the sieve analysis did not shed much light on the pebble lenses, specifically their origins. A specific study of the compositional make up of the pebble lens materials did not reveal any materials that could not have been so derived from the materials found in the cave’s interior. The pebble lensed did contain a slightly higher percentage of the coarse fractions, here Mesh sizes 10, 18 and 35. But, overall, there was no large statistical difference between the pebble and the non-pebble lens intervals.

Do they, again, represent the backfill of animal burrows and living spaces? Or do they, perhaps, represent a mini-slurry or debris flows made up chiefly of cave floor materials that have been wept up by a sudden small rush of water associated with an sudden and intense rainstorm; a slurry that became sluggish as it dried out in its journey across otherwise dry cave floor sediments? This flush of water would have to be of such a limited volume so as to gather up only the loose surface materials to form wet slurry of materials. Initially this slurry had enough mass to travel downslope to where it begins to lose energy as it accumulates additional dry materials that, in turn, dry it out to the point where all forward motion stops. That forward motion could have carried the mixture into an animal burrow or a human-made depression where it might assume the lazy balloon shapes seen in the south-wall profile of Unit 2. On the whole, however, this is a scenario that is not only hard to visualize but also one to support with any degree of confidence. A more definitive answer would require a detailed (in situ) inspection of the pebble lenses and, in particular, their relationship with the enclosing sediments.

Finally, I did not see any definitive evidence of human use and/or occupation of the cave in any of the interval samples and/or their individual size fractions. Some samples did have noticeable pieces of burnt wood and ash; however, these could have easily originated outside the cave as a result of wildfire activity and been carried into the cave by either wind or water. The few small pieces of baked shale seen in several samples was soft and not of the porcellanite variety. These pieces of baked shale could have just as easily been naturally introduced into the cave by the overland flow of water carrying pieces of burnt shale downslope and into the cave though the cracks its ceiling. Sources of baked shale can be found in the rock units that are a little more than a hundred meters above the cave site.

However, when I took the (marker interval) sieve results (Figure 23) and overlaid them onto Fisher's South Wall Unit 2 profile (Figure 21) some interesting cultural feature patterns emerged (Figure 25). Namely, the hearth features seen in Figure 21 occur either immediately following or preceding one of the "dry episodes."

This strongly suggests that this part of southeastern Montana may not have been a favorable environment during the dry episodes. In short, a reduction in precipitation would bring on a corresponding reduction in vegetation; here plant species not only important to foraging humans but necessary to sustaining large ungulates such as bison, deer, elk and antelope as well. This would very likely result in a significant shift in the patterns and style of hunting, gathering and residence. This is not to imply that the Northern Plains were totally devoid of human occupants during this time. For sure, even today hunter-gatherer peoples successfully occupy many desert areas. But to do so, their diet choses will, by necessity, have to be broader than that associated with life on a landscape well populated with large-sized mammals such as bison, deer,

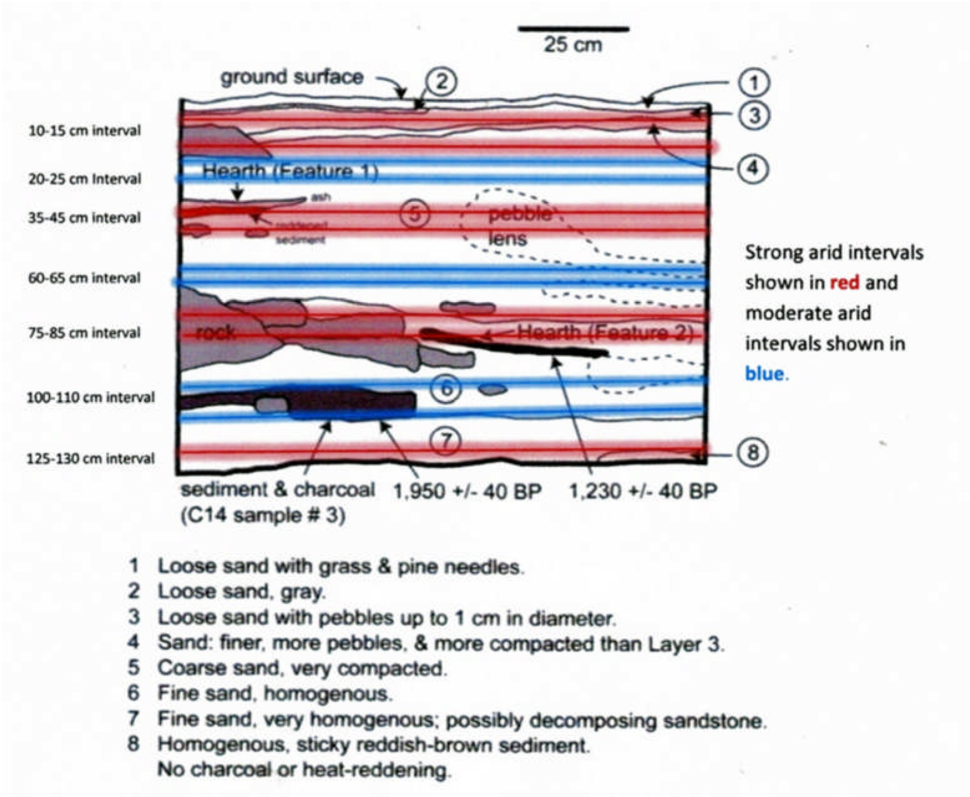


Figure 25. Arid intervals from Figure 23 overlain on Unit 2 South Wall Profile (Figure 21).

elk and antelope and with valley/creek bottoms that are well stocked with vegetative resources that provide a wide variety of edible berries and seeds (Kelly 1995:73-90). On the other hand, the (human) carrying capacity of an arid area can not approach that of more mesic one.

Frison (1991:79-83 and 191-194), Frison et al. (1976:33-34) and Fagan (1991:120-122) note the human response to the Altithermal, a prolong warm and dry period during Early Plains Archaic times, on the Northern Plains was to seek out those environments more favorable to meeting their daily needs; areas such as the foothills and the upper reaches of the Big Horn Mountains and the Black Hills.

Therefore, it may well be that the absence of hearth features during the "dry-time intervals" are a reflection of reduced use during arid times.

Fisher 2010

As outlined above, the 2010 field research strategy was to provide information that would both compliment and expand upon the information provided by the 2008 investigation. Another objective of the 2010 work was to provide a better understanding of the processes that were involved in the formation of the cave. To this end, three unit locations were selected: the first, Unit 3, would be located toward the backend of the cave; the second unit, Unit 4, would be located at the front of the cave; and the third, Unit 5, would be located some distance from the cave opening.

Unit 3. Unit 3 was located to the immediate southwest of Unit 1, a location somewhat deeper into the cave. In many respects, the setting and findings associated with Unit 3 proved to be almost identical to those of Unit 1. A majority of the floor fill consisted of a loose accumulation of soft, light-colored sandstone punctuated in places by small pieces of ceiling rock, a testimony to past rock-fall events. An exception to this picture is the south wall of the unit and, in particular, its southwest corner. Here some of rock fall was so large that it could not be removed without mechanical assistance. Because such assistance was not available, these large rock masses were left in place.

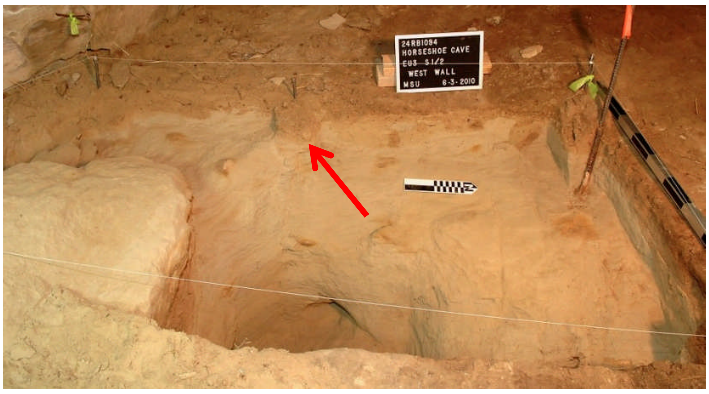


Figure 26. West wall of Unit 3. Note large block of fallen wall-rock on left. Red arrow points to possible channel-way. Photograph used by permission of Jack Fisher, 06/03/2010.

Along the west and north margins of Unit 3 the excavation "bottomed out" at about 50 cm (20 in.) on what could have been either a large slab of (soft) sandstone that had come from the south wall or was, in fact, the bedrock floor of the cave (Figure 26). This same question was raised during the 2008 excavation of Unit 1. The “bedrock” along the south wall of Unit 1 has encountered at about 110 cm or about twice as deep as that reported above for Unit 3. This question of rock fall or bedrock floor could, perhaps, be resolved through deeper excavation and/or the use of ground-penetrating radar (GPR).

While no cultural features and/or materials were found by the excavation it did reveal two interesting geologic features. One of those features is a small gouge like depression on the west wall and the other is a area of “cut-and-fill” structures on its north wall. The small gouge like feature is seen approximately in the mid-portion of the west wall (Figure 25). This structure would likely go unnoticed if it were not for the orange-brown discoloration of its fill material. This material appears to be filling a small v-shaped cut or valley-like feature that has a west to east trend or, essentially, the direction of flow that one would expect of any water originating in the back of the cave and flowing outward toward its mouth.

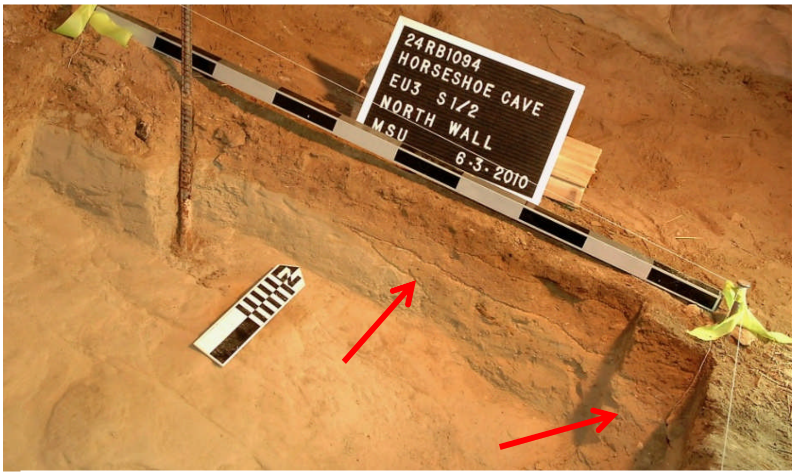


Figure 27. North wall of Unit 3. Red arrows identify possible cut-and-fill features. Photograph used by permission of Jack Fisher, taken 06/03-2010.

What look like small cut and fill structures can be seen in the mid and east portions of the north wall (Figure 27). In addition, the sediments within the north wall appear to be sloped downward to the east or open end of the cave. When viewing this sedimentary one has the sense that moderately flowing water cut away sediments as it moved across the floor and these cuts, in turn, could have been filled-in by the same or subsequent water flows or the rain of sand grains coming from the cave's walls and ceiling. Quite possibly, human activity could also account for these cut-and-fill features, however no cultural evidence was found in this area to confirm such a supposition.

One other characteristic of Unit 3 worth noting is the average grain-size and compositional makeup of the screened materials. As reported in Table 2, this material has an average grain-size of less than 0.25 mm (0.02-0.003 in.) or fine to very-fine sand. Furthermore, very little of the screened material fell into the silt to clay size classes, which are less than 0.08 mm (<0.003 in.). It's my view that this indicates that there has been little input from the thick shale and clay units immediately overlying the cave's sandstone units. This lack of fines is a strong indication that flowing water in the cave is not a direct effect of overland flow but rather the accumulation of fluids that have first filtered through both the overlying soil and cap-rock sandstone before reaching the cave-forming wall-rock unit; once finding its way into the cave the various streams of this moisture began gathering in the cave's rear to form a small stream of water that then moved toward the cave's mouth with enough force to carve away materials and form a cave-like void. If this water had not, in some way, been subjected to a filtering process, I would expect to see a greater percentage of shale and clay sized materials present in the cave floor sediments. Instead, the greater percentage of floor materials consists of sand-sized grains similar, in most respects, to the cap-rock and wall-rock units.

Unit 4. Unit 4 was located just in front of the cave's drip-line near its northern corner. Given this unit's location, it should come as no surprise that much of the material found during excavation consisted of small- to medium-sized pieces of cap-rock (Figure 27). The dimensions of these materials ranged in size from less than 10 to more than 70 mm (4-28 in.). These are pieces and blocks of rock that mark the gradual retreat of the cave's outer margins and, perhaps, the loss of some of its depth. Similar retreats can be seen all along the margins of the sandstone scarp that hosts both Horseshoe and Finger caves.

A dark band of charcoal or ash is found at about the 20 cm (8 in.) level (Figure 28). Whether this represents materials associated with past human-use of the site or area wildfires could not be determined as the other materials encountered and/or removed from the unit during excavation offered no clues in this regard.

Figure 28. Unit 4 at completion. Red arrow identifies band of charcoal. Photograph by Norman Smyers, 06/03/2010.

Using a hand-texturing analysis technique, I classified the fine-fractions at the deepest level of the unit as a Sandy loam. This is an indication that at this excavation level fine-grained materials represent a mix of cave-hosting sandstone, silt and clay derived from overlying units, and eolian sediments (very fine sand to clay sized fractions).

Aside from the charcoal layer mentioned above, no other material with cultural potential was found in the excavation of Unit 4.

Unit 5. This unit was placed in an open grassy area approximately 20 m (66 ft.) northeast of the cave opening. The sedimentary profile consisted of an 8-10 cm (3-4 in.) thick O horizon overlying a Clay loam A horizon that extends to the unit's finished depth of a little less than 1 m (3 ft.).

This Clay loam horizon was marked in places by 5.0 cm (1-2 in.) bands of carbon rich soil (Figure 30). The presence of this thick Clay loam A horizon suggests the existence of a somewhat long and stable period in the history of the unnamed drainage where Horseshoe Cave

Figure 29. West wall of Unit 5. Red arrows identify bands of carbon rich soil. Photograph used by permission of Jack Fisher, 06/03/2010.

is located. Perhaps during the period of time this unit was forming the base-level of the region was such that down-cutting was markedly reduced. In such an environment, rather than being washed away, fine-grained sediments could accumulate and develop into an organically rich clay loam soil. The several thick bands of carbon rich soils appear to represent past wildfire events. The almost regular spacing of these bands suggests some periodicity in the fire-cycle.

When excavation ceased, I inserted a soil probe 29 cm (11.5 in.) long into the floor of the unit. The recovered core was Clay loam. Clearly, this Clay loam A horizon extends at least another 50 cm (20 in). Perhaps, even more?

The long stable "quiet time nature" associated with the development of an A horizon contrasts sharply with the current condition of the drainage as its eroded banks and V-shaped cross section suggests a vigorous intermittent watercourse frequently visited by violent thunderstorm flood events. Also, a lowering or deepening of the region's erosional base-level will result in a corresponding increase in stream-course gradient that can lead to increased bank erosion and down-cutting.

As noted by Thornbury (1954:105) and Hamblin (1994:169) there is a limit to downward deepening by streams and rivers, this limit is known as "base-level." In short, a stream or river can not erode lower than the level of the stream, lake, or marine system into which it flows (Hamblin 1994:169). However, over the course of geologic time, base-level is never constant.

Changes in base-level can be on either a local or regional scale. Base-level may increase or decrease due to tectonic movements of the land surface, the loss of vegetative cover, and depositional infill of the geographic system into which the stream or river flows.

Uplift of the land surface can lead to an increase in stream gradients that, in turn, allows for increased down cutting and erosion. Erosion can also be increased or decreased by a loss or gain of protective vegetative cover; such losses or gains can be brought on by climate change or they may be the result of increased or decreased domestic livestock grazing. In my opinion, the most likely cause of any modern increase of erosion in the Poker Jim Creek drainage would be the loss of protective vegetative cover due to marked increase in domestic livestock grazing, principally beef cattle, that began in earnest a little less than 150 years ago with the arrival of the railroads in the late 1800s (Spritzer 1999:7; Van West 1986:24).

In a search of the geologic literature I could find no reference to the base-level, local or regional, for northeastern Wyoming and southeastern Montana. Thus it should be noted that any proposed change in the condition of the regional and local base-levels is premised solely on speculation. This is particularly important in the discussion, below, regarding a scenario for the formation of Horseshoe Cave.

As expected, no cultural materials were found during the excavation of this unit.

CAVE FORMATION--A SCENARIO

Several idealized models of cave formation are described and well illustrated by Rapp and Hill (2006:81-86), Goldberg and Macphail (2006:172:174), Waters (1992:240-247) and Donahue and Adovasio (1990:232-235). In general, the descriptions and illustrations provided by these authors favor caves and rockshelters formed in limestone units. Rapp and Hill (2006:85), on the other hand, have expanded their treatment to include those formed in sandstone units as well.

Perhaps this somewhat uneven lithologic treatment is due to the numerical frequency if not the durability, that limestone caves and rockshelters have over those found in softer sedimentary rocks such as sandstone. Without question, the characteristics of limestone are definitely more favorable to the formation of cave and rockshelter type features that are, in general, larger and more durable than those created in other rock types--be they igneous, metamorphic, or sedimentary.

A question that frequently arises during any discussion regarding caves and rockshelters is what is the difference between the two? In this regard, it is also worth noting that Rapp and Hill (2006:81-86), Goldberg and Macphail (2006:172:174), and Waters (1992:240-247) offer some opinions on what, size-wise, separates a cave from a rockshelter. In my opinion, these discussions are more academic than they are relevant to the formation of Horseshoe Cave and, therefore, will not be considered here.

For me, a rockshelter is a somewhat shallow depression or cut into a rock unit that provides for some short-time protection from inclement weather. Caves, on the other hand, should provide for more than just short-time comfort or protection. Given these differences, I would consider the subject feature to be a cave as opposed to a rockshelter in that its size invites use during all times of the year, not just those times when protection is needed from a weather event of limited duration, e.g. a thunderstorm, cold night and/or snowstorm.

With respect to Horseshoe Cave, the following discussion regarding cave forming processes will rely heavily on the review and illustrations provided by Rapp and Hill (2006: Figure 3.11) and Waters (1992: Figure 5.13). Of the two, it is my opinion that Waters' (1992:5.13) illustration is an almost textbook example of Horseshoe Cave (Figure 30). If there is an exception in his illustration it is the dripstone (stalactites) and flowstone features seen at the back of the cave. These are features more characteristic of a limestone cave as opposed to a sandstone one. On the other hand, as we have seen, small gypsum speleothems were present on the ceiling of Horseshoe Cave, features that could be considered analogous to (limestone) stalactites. Otherwise, all the features illustrated by Waters (1992:5.13) are present at Horseshoe Cave.

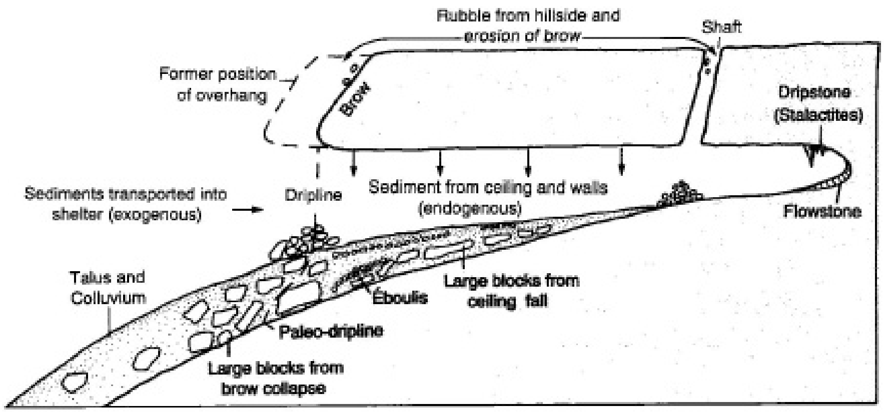


Figure 30. Generalized cross-section of a cave or rockshelter.
From Waters 1992:Figure 5.13.

The illustration provided by Rapp and Hill (2006:Figure 3.11) shows the various stages and processes associated with the development of a rockshelter (Figure 31). But if one were to offer their (Rapp and Hill 2006:Figure 3.11) "rockshelter" added time and development without collapse, as shown in their Stage 5 frame, the result would closely mimic that of present day Horseshoe Cave.

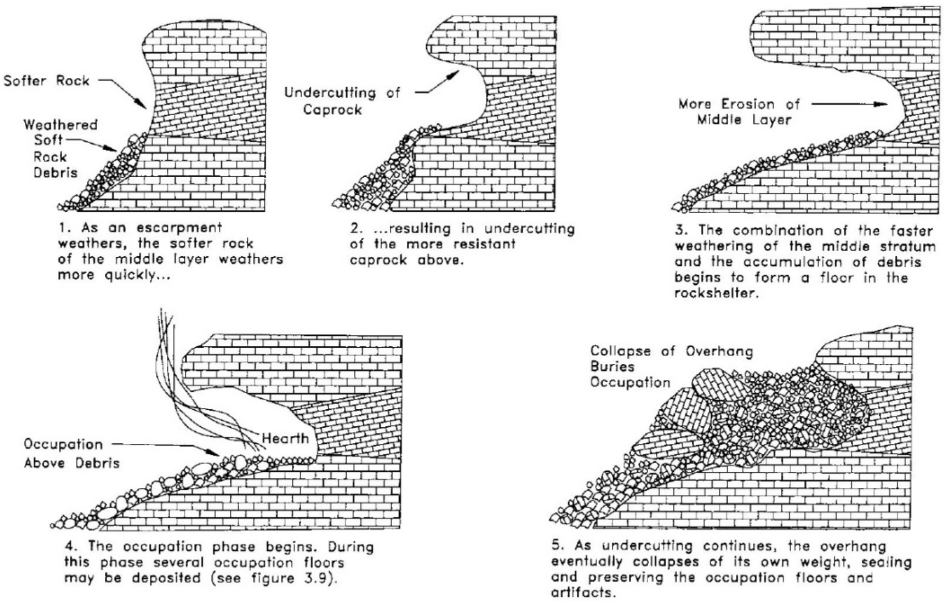


Figure 31. Evolution of a rock shelter. From Rapp and Hill 2006:Figure 3.11.

I need to mention that I saw no evidence which would suggest that there has been any human action or involvement in the development of the cave, e.g. large scale basket removal of dirt and rock and/or construction of a rock wall at the cave's entrance, etc. On the other hand, it is more than likely that some of the cave users may have excavated and/or moved some of the fine-grained floor sediments and rock-fall around and within the cave to suit their needs. Likewise, there is no indication that there has been any large-scale human removal of sediment and/or rock from or into the cave—aside from that associated with the past four archaeological investigations. Based on my survey of the Horseshoe Cave site, my analysis of the cap and wall rock samples, my observations regarding the characteristics of the 2008 Unit 2 re-opened in 2011, the three excavation units opened during the 2010 investigation, and my review of the results of the findings of McLean's 1976 and Fisher's 2008 investigation, my image of the formation of Horseshoe Cave is as follows:

In the beginning lithologic and structural elements of two sandstone units combined to form a setting in which softer and less resistant rock could be carved out or removed from beneath a harder and more resistant one. The factors allowing for such development include an overlying cap-rock sandstone bed with a higher degree of (calcite) cementation than the underlying and less well (calcite) cemented wall-rock unit. Small fractures in the cap-rock unit allowed water to work its way into the underlying softer sandstone thereby increasing its rate of weathering and removal (Stages 1-3 of Rapp and Hill 2006:83). *Eventually, the face of the cave-forming wall-rock unit would retreat far enough into the hillside thus providing a shallow protective overhang, a feature with enough depth and size to provide, at best, some temporary shelter from the elements.*

Continued weathering and erosion of the overlying cap-rock unit allowed some of the fractures to increase in size which subsequently permitted increasing volumes of water to move through the softer sandstone which then allowed for the removal of an ever increasing amount of the softer sandstone (Stage 3 of Rapp and Hill 2006:83).

The base-level of the drainage in which Horseshoe Cave is located was lower than it is at present (See *Excavation 5* above for an explanation of base-level and its significance to this scenario). *Therefore, the elevational gradient between the cave floor and the bed of this drainage was significantly steeper than it is at the present time. This increased elevational* *difference between the cave floor and drainage bottom increased the rock removal effects of mass and water erosion.* (Note: While none of the (cave) profiles in the three units opened by Fisher in 2008 and 2010 show evidence of strong or vigorous water activity, this may be because the evidence lies at a depth below that reached by any of his excavations, evidence now covered by particles and pieces of weathered and fallen rock. These units do, however, display some of potential effects of water erosion).

As materials were carried out of the cave as well as down from the adjacent slopes and into the surrounding drainages, the base-level of the North Fork and its tributary drainages began to rise thereby decreasing not only the gradient between the cave and its adjacent creek but also the rock-removing capabilities of both mass wasting and water erosion. (Note: A period of raised base-level and quiescence of vigorous erosion is consistent with the thick Clay loam soil profile seen in Unit 5).

Within the cave, a decreased gradient allowed for weathered sand-grains, fallen ceiling and wall rock, plant and animal debris, and airborne dust and dirt to produce a smooth floor (Stage 4 of Rapp and Hill 2006:83). *It is at this stage of development that Horseshoe Cave could provide people with more than just limited protection from the elements; Horseshoe Cave would now have reached a point where it could now comfortably meet long-term human occupancy needs.*

The vertical shaft feature in the cave's midpoint (See Figure 30) could have only formed after the process of cave enlargement and deepening had extended past this point of occurrence (Late Stage 3 or Stage 4 of Rapp and Hill 2006:83). *Therefore, prior to this time it is somewhat unlikely that the shaft in any way could have been a source of erosive water in the cave's* *development. Moreover, the process of cave enlargement and growth must be viewed as a slow process of rock weathering and breakdown that was marked by periodic (erosive) removal of materials by small rivulets of water flowing through and from the many small joints and fissures cut into the sandstone cap and wall rock units. In the early stages of development, a steep gradient both within and outside the cave allowed for loosened materials to move freely across the cave-floor and past the cave's drip-line on their journey to the (unnamed) drainage east of the cave.*

Geologic features seen in the at the east end of the profile of the south wall of Unit 2 (Figure 21) and in Unit 4 (Figure 27) indicate that roof-fall along the outer edge of the cave's opening has acted as a dam or catchment for materials attempting to move out of the cave (Stage 4 of Rapp and Hill 2006:83). *It is very likely that this is the sort of cave breakdown that allowed for finer materials to begin leveling the cave floor to produce a somewhat level surface floor, one that is surely more conducive to human use and occupation than that is uneven and strewn with large pieces of rock.*

At some point in the cave's future, portions of the cap-rock will fall into its interior (Stage 5 of Rapp and Hill 2006:83). *Evidence of such collapse can be seen in several of the nearby drainages. Here, rockshelters and, possibly, caves of unknown dimension now lie buried beneath a jumble of large car-sized blocks of sandstone. Even today, large blocks of sandstone litter the ground to the front and sides of the opening to Horseshoe Cave.*

There are two reasonable questions that can be asked regarding the above cave development scenario: first, when did the process begin, and second, what is the length of time it took to create the cave in its current form?

While these are worthy questions, they are questions that can not be answered without additional rigorous research. That research would include, at a minimum, extensive soil and sediment coring, radiocarbon analysis of recovered soils and sediments, regional watershed development analysis, past climate analysis, and a means by which the sedimentary sequence at the front of the cave can be opened for inspection.

Taken together, those data might suggest an initiation date or time for the development of the cave. These data could also provide clues as to when the cave attained, more or less, its current form. In addition, such knowledge could also provide valuable insight with regards to the timing of the human use and occupation of the cave. But in sum, it would be an expensive undertaking in both time and cost.

As a guess, I would say that cave development began at least several thousands of years ago, if not tens of thousands of years ago. The speed of development, however, would depend to a large degree on past climatic factors, e.g. warm and dry periods vs. cool and wet periods. In this regard, one would expect the cave development process to be "accelerated" during cool and wet periods when there would be more moisture available to flow through the cave and remove the soft sand (grains) making up the floor. In addition, more moisture means more water becoming lodged between individual grains of the sandstone rocks surrounding the cave-void, moisture that would, through repeated freeze/thaw cycles, loosen grains so that they could fall and be added to the other debris making up the floor sediments (Stein and Farrand 1985:25-27). But on that note, this is a question regarding the developmental process that would, again, benefit from additional work and analysis.

Some may hasten to point out that the diagnostic artifacts and radiocarbon dates already obtained from the cave provide some idea as to its antiquity. While this is somewhat true, in my opinion these cultural features could have only been introduced into the cave's setting rather late in its physical development, at the very earliest, perhaps Stage 3 of Rapp and Hill (2006:83). Even then, we know little as to how long it would have taken to get to that stage of development from when the cave forming process was initiated.

PRE-CONTACT NATIVE AMERICAN USE OF GEOLOGIC RESOURCES

The following discussions are intended to provide some greater depth and understanding of the geoarchaeological attributes of Horseshoe Cave and its immediate surroundings when they are compared to the greater regional area of southeastern Montana and northeastern Wyoming.

Porcellanite

Porcellanite is one of the more abundant naturally occurring (geologic) materials in the part of southeastern Montana that readily lends itself to being fashioned into a tool that can bear a sharp edge. As described above, porcellanite is a by-product of coal fires. It is created when the (often) intense heat of a coal fire melts silicon rich silt and clay materials to form a glassy product. In a word, porcellanite can have many of the same properties as obsidian; that is, it can be shaped to form a tool with a sharp edge.

Within the North Fork drainage the thick, dark red beds along the high ridges to the north of the cave provide evidence of past coal bed fires. During the 2010 field investigation, Clint Garrett and River Lovec reported that they had encountered porcellanite deposits within many of these burnt coal units, thus establishing that sources of porcellanite do exist within the North Fork drainage. This should come as no surprise to any archaeologist and/or geologist who have conducted investigative work within this drainage as most of its north-side drainages contain small to medium-sized pieces of porcellanite. The pieces are, of course, materials that have been carried downhill from their respective parent beds by the overland flow of water.

Regionally the occurrence of porcellanite is definitely not limited to the North Fork drainage. However, absent any detailed provenance studies no one can categorically state that porcellanite artifacts found within the North Fork drainage had their origins in any particular location within southeastern Montana or northern Wyoming. This is because burnt coal beds are common throughout the entire region. As a consequence, North Fork drainage can not be ruled out as a possible porcellanite source for such artifacts.

Coal

Although modern society makes large use of coal to meets it needs for space heat and electrical generation, there is no evidence to suggest that pre-contact peoples in southeastern Montana ever used coal for heating and /or cooking purposes. In many ways, this lack of evidence is somewhat puzzling as one would suspect that these same peoples, from time-to-time, must have surely encountered burning coals beds that would have demonstrated to them that coal could be used as a heat source.

Caves and Rockshelters

In an anthropologic sense, cave and rockshelter features are as much a geologic resource here as are porcellanite and coal. In this context, Finger, Horseshoe and other cave-like features scattered throughout southeastern Montana provide abundant archaeological evidence that humans made use of these products of weathering and erosion.

Cave Frequency and Use. A common question among the participants of the 2010 investigation was how common or unique are Horseshoe Cave like features in southeastern Montana and northeastern Wyoming? Archaeologically this is an important question as any answer may have important implications to the past human uses and occupation of the subject site. Namely, was it a location used for long-term habitation or one associated temporary special use, namely ceremonial activities or during hunting excursions? In that same context, was cave use, as opposed to rockshelter use, a common practice for pre-contact peoples of the Northern Plains? Or does Horseshoe Cave represent a somewhat unique occurrence?

It goes without saying that the availability of cave-like structures could be a strong determinant in any such assessment. Therefore, in order to shed some light on this issue, I undertook a preliminary review of the recorded occurrence of both rockshelters and caves in southeastern Montana that exhibit evidence of past human use. To that end, the following discussion is not a quantitative or statistical measure of the frequency of cave and rockshelter features in southeastern Montana. Rather, it should be considered as a quick assessment of the occurrence of such features.

I limited my review to southeastern Montana. This was an approach that I undertook both in the interest of time and effort. But it was an approach also taken because of better access to the site records maintained by the Montana State Historic Preservation Office. It can be rightfully argued that by ignoring a review of cave and rockshelter use in northeastern Wyoming the validity of any of my findings is limited. In that regard, this is a possibility that I have to accept without argument. However, early in my process I decided that if my site queries for southeastern Montana yielded a lot of cave sites I would then extend my survey interests to northeastern Wyoming. As the results below demonstrate, only a few sites similar to Horseshoe Cave have been reported for southeastern Montana. Thus, I decided against pursuing a Wyoming inquiry, as I didn’t think that it would add much to this cursory level of research.

Southeastern Montana. To initiate my assessment of the occurrence of cave and rockshelter features in southeastern Montana, I contacted Damon Murdo, Cultural Records Manager for the Montana State Historic Preservation Office in Helena, Montana. From him, I requested a data query using the search term words “cave,” “rockshelter,” and “cave and rockshelters.” Additionally, I requested that this data query to include recorded sites in Big Horn, Carbon, Carter, Custer, Powder River, Rosebud, Treasure, and Yellowstone Counties--eight counties in all.

The search resulted in 268 listings. The output provided the site number, geographic locations (township/range, section and quarter section coordinates), and Site Types 1 and 2 which used the data query descriptors noted above.

While my initial intent was to review the site record for each listing returned by query, in the end the length of the list led me to narrow the focus to a more detailed review of the listings for five counties: Big Horn, 96; Custer, 3; Carter, 18; Powder River, 30; and Rosebud, 36. Even then, the total number of listings for these five counties totaled 183, with a little more than half of these from Big Horn County.

From these 183 listings I selected the site report records 25 listings for a close review. In sum, my review included seven (7) sites from the eastern margins of Big Horn County (the portion nearest Horseshoe Cave), one (1) site from Custer County, two (2) sites from Carter County, nine (9) sites from Powder River County, and six (6) sites from Rosebud County, the county in which Horseshoe Cave is located. The site designation number of the twenty-five sites can be found in Appendix C.

What drew my attention to these 25 sites was the use of site type keyword descriptors such as “Rock Shelter or Cave,” “Lithic Scatter,” “Petroglyph,” “Fire hearths or Roasting Pits,” and “FCR” or “fire cracked rock.” I felt these descriptors indicated more than a temporary or passing use of a site.

By-and-large, most of the recorded sites in southeastern Montana proved to be rockshelters or sites beneath overhangs that allowed limited refuge from such adverse weather conditions as rain, snow, and heat. To provide protection from extreme adverse weather conditions, most of these sites would require substantive use of heating fires and/or the construction of protective barriers (most likely stacked rocks, stones, and tree branches and trunks). A casual review of the dimensions of a large number of these “rockshelter” sites showed an average height of about 1.5 to 2 m (5-6 ft.), a width ranging from 3 to 4 m (6-12 ft.), and a depth rarely of more than 2 to 3 m (6-10 ft.). The area of useable space was on the order of 20-25 m^2 (215-220 $ft.^2$).

All of these recorded rockshelter sites displayed evidence of past human use. Artifactual evidence of occupation and use includes lithic scatters, animal bones with evidence of human use, fire-cracked-rock, charcoal, hearth features, and smoke-blacked ceilings.

By slightly expanding the query search area, two caves can be found that are close to and/or exceed the dimensions of Horseshoe Cave. These two exceptions are Pictograph Cave immediately south of Billings, Montana and Ludlow Cave in the extreme northwestern corner of South Dakota.

Whereas Pictograph Cave was well known to the residents of early residents of Billings it wasn’t until the late 1930s that it received serious archeological attention (Kooistra-Manning 2001:80). Working under the auspices of the Works Progress Administration (WPA), Oscar Lewis and, eventually, William Malloy recorded the prolific rock art found at the site and, as well, conducted extensive excavations that revealed history of human use history that extended back more than 5,000 years (Kooistra-Manning 2001:80-81).

Ludlow Cave is located just a few miles east of the boundary-line between Montana and South Dakota and within the Short Pines hills of Carter County, on Federal lands managed by the Sioux Ranger District of the Custer National Forest (Beckes and Keyser 1983:210-263). W. H. Over (1936) conducted an detailed investigation of the site in the 1920s. His (Over 1936:126-129) work disclosed the cave had a long history of use, one that included extended periods of occupation as well as use as a spiritual site.

North Fork of Poker Jim Creek. The two primary objectives for the site surveys conducted during the 2010 investigation were: first, to locate and record sites that exhibit evidence of past human use and/or occupation; and, second, to locate and record any other cave and/or rockshelter features that could have provided for human use and occupation--in other words, sites that possessed characteristics similar to those found at Horseshoe and Finger caves. With one exception, the site survey teams found none.

That one exception was a site that I encountered in a small drainage about 1.6 km (1 mi.) east of Horseshoe Cave and just off a major south trending branch of the North Fork of Poker Jim Creek. Unfortunately, a thick sand of poison oak precluded my close inspection of this feature. From a distance of about 15 m (50 ft.), the opening to this feature appeared to be about 1.5 to 2 m (5-6 ft.) high, 5 to 8 m (15-26 ft.) wide, and with an estimated visible depth approaching 7 m (23 ft.). It exhibited, however, a low degree of desirability for human habitation in that it was located within and beneath the channel way of, what appeared to be, an intermittent drainage. Therefore, any water coming down this drainage would flow over the site and pour, waterfall like, over the structure’s overhang. This was a feature that might be tolerable during dry times but would not be a suitable location during times when there is any volume of

Figure 32. Small over-hang, North Fork of Poker Jim Creek. Individual in background is Ivy Merriot. Photograph by Norman Smyers, 05/29/2010.

runoff coming down the drainage. From an archaeological standpoint, this feature looked interesting but, absent a close-up inspection, impossible to assess with any degree of confidence.

The North Fork drainage did, on the other hand, contain numerous rockshelter like features. Typically, these examples are found near the base of near-vertical outcrops and consist of recesses that extend a meter or two (3-6 ft.) in from the forward edge of a sandstone rock overhang (Figure 32).

Few of these rockshelter features appeared deep enough or tall enough to offer comfortable long-term refuge from such adverse weather elements as driving rain, snow, cold and heat. In addition, many of these recesses were located on steep slopes, positions which forced their floors to slope sharply down and outward from their backs. In my view, none of these sites appeared to be favorable for long-term use or occupation. Additionally, few of these sites displayed any evidence, such as lithic scatter, that would indicate past human use.

Horseshoe Cave: A Unique Occurrence. Unfortunately many archeological sites within southeastern Montana have been disturbed by looters. This is true for many of those reviewed for this study as well. Therefore, there is a high probability that much of the (archaeological) contextual value of many of these sites has already been compromised or lost. Furthermore, in many cases little professional effort as so far been directed at the study of many of these sites. In this regard, Horseshoe Cave is an exception.

Overall, it might be said that the occurrence of caves and rockshelter sites in southeastern Montana with the size and dimensions seen at Horseshoe Cave are uncommon, if not unusual. In addition, it is very likely that Horseshoe Cave has the distinction of not having been disturbed prior to Gary McLean's 1976 investigation. As mentioned before, when Beckes (personal communication, January 2, 2011) visited the site in 1973 he saw no evidence that it had been disturbed to the same degree seen at other sites in southeastern Montana--that is, sites heavily impacted by pot hunting activities. Again, Horseshoe Cave is one of the few sites which have received repeated archaeological investigations. Collectively, these factors make Horseshoe a unique archaeological site for southeastern Montana and one where additional archaeological investigations have the potential to expand our knowledge of the archaeological past of southeastern Montana.

SUGGESTIONS FOR FURTHER RESEARCH

After reviewing the results of the four investigations conducted at Horseshoe Cave, I have identified two actions that I believe should be pursued if any further investigation is to be conducted at this site.

Ground Penetrating Radar (GPR)

Before any new excavation studies are undertaken within the cave, the entire cave floor should be first subjected to a ground-penetrating-radar (GPR) survey. In conditions similar to those found at Horseshoe Cave, modern GPR survey equipment can penetrate, with good definition of detail, to 15 m (49 ft.) (Wikipedia 2012; GPR Data Inc. 2012). Thus a GPR survey will allow for the topographic mapping of the bedrock floor that lies below the loose sediment cover as well as sediments underlying denser pieces of fall-rock materials. Such mapping may reveal much information regarding the formative development of the cave, e.g. if water was an active ingredient in development of the cave, by identifying and mapping the channels.

A GPR survey will also reveal whether or not the "…soft, light-colored sandstone…" that terminated Fisher's (2008) Unit 1 excavation was fallen wall-rock or the solid bedrock floor of the cave; the same question was repeated when the 2010 Unit 3 excavation was terminated for much the same reason. Again, a GPR survey may be able to answer this question without the need for further excavation.

A GPR survey would also provide information as to whether or not the fallen blocks of wall or cap rock are hiding cultural materials. Essentially, the survey can disclose whether or not pockets of loose floor sediments lie below the large pieces of wall and ceiling rock that litter the floor of the cave, pockets that might contain artifactual materials. Again, in such a situation, a GPR survey would be a useful aid in laying out excavation units with a good potential to yield a maximum amount of archaeological information.

Given the sandy make up of the floor cover, one would expect good GPR survey results. Loose, dry aggregate and fill are generally a good medium for a GPR survey. Conversely, clay is a poor medium for such surveys as it tends to attenuate the input signal. But the results of past excavations and my sieving analysis show (fine-grained) sand to be the larger part of the materials making up the floor fill and only a small portion of that fill falls into the silt and clay size range. Therefore, a GPR survey within the cave proper should produce good results. However, just outside the cave's drip-line the percentage of clay sized materials increases as demonstrated by Sandy loam and Clay loam soils encountered in 2010's Units 4 and 5. Nevertheless, it would still be wise to extend the GPR survey at least a meter or two beyond (east) the cave's drip line as it may provide information regarding the geologic processes responsible for the creation of the cave and areas that have the potential for possessing cultural features and materials.

Deeper Excavations

After comparing the results of McLean's 1976 excavation with those of Fisher's 2008 and 2010 investigations one thing becomes readily apparent--archaeological materials are more likely to be encountered at depths greater than those reached by Fisher's investigations. To replicate To replicate To replicate To replicate To replicate In short, to replicate the results of McLean's (1976) work the excavations need to go at least 1.0 to 1.5 m (3-5 feet) deeper.

Clearly, the areas where McLean found artifactual materials in 1976, the depth of the sedimentary fill was much greater than that encountered by Fisher during his 2008 and 2010 excavations. On top of that, the areas in front of the cave appear to have deeper fill. Aside from Units 4 and 5, Fisher's excavations have been, for the most part, deeper into the cave. In any case, it appears that there may be a better chance at recovering artifactual material and data when excavations extend to a depth of 2-3 m (6-9 ft.) or more.

SUMMARY CONCLUSIONS

Horseshoe Cave is but a small feature that is found in an extensive geologic assemblage of Early Tertiary rocks that crop out across north-central Wyoming and south-central Montana. Horseshoe Cave lies at the northern tip of this area which is referred to as the Powder River Basin. These Early Tertiary rocks belong to the Fort Union Formation, a thick wedge of sedimentary rocks deposited in the basin over a period of some 10 million years, from approximately 55 to 45 million years ago. It is also the rock group into which Horseshoe Cave was carved.

Reports by McLean (1976) and Fisher (2010a. 2010b and 2011) demonstrate that continued archaeological work Horseshoe Cave has the potential to provide additional information about the cultural past of southeastern Montana. McLean's (1976:70-88) excavations revealed multiple hearth features, a bone tool, lithic flakes and projectile points, and the remains of animals whose presence is due to past human actions. While Fisher's (2010a and 2010b) work at the site has yet to recovery a volume of materials comparable to those of McLean, the animal bones, lithic flakes and broken projectile points demonstrate that further work at the site is warranted.

Because of the cultural features and materials so far discovered at Horseshoe Cave, five questions have been raised with respect to the geologic history and make up of the cave and its immediate surroundings, a history and composition which may have influenced past human uses of the cave as well as its adjacent terrain. <u>First</u>, how was Horseshoe Cave formed; <u>second</u>, what is the rate of sedimentation within the cave; <u>third</u>, what are the sources of sediment found within the cave; <u>fourth</u>, how does the sedimentological and/or depositional setting within the cave differ from that outside the cave; and, <u>fifth</u>, what is the nature of the depositional variability across the cave? Answering these five questions is the primary purpose of this geoarchaeological report.

First Question

For any rockshelter or cave to form requires the presence of rock units of unequal durability. In simple terms, the presence of a cap-rock unit that is more resistant to weathering and erosion than an underlying one. In the case of Horseshoe Cave, this needed rock combination is two sandstone units of the Tongue River Member of the Fort Union Formation.

But what makes the cap-rock unit the more durable of the two? The results of my 2010 investigative work show that the cap-rock unit has nearly double the amount of calcite cement than does the underlying sandstone unit which has been removed to form the cave-void. In short, the difference in cementation is the key factor to explaining why the cap-rock is significantly more resistant to the effects of weathering and erosion than the underlying cave-forming wall-rock.

At some point in the distant past when the hillsides and gradients of the region's drainages were steeper, the less indurated or sandstone unit began to weather and crumble away. Water moving through the cracks and joints in the cap-rock then passed into the softer cave-forming sandstone unit, this accelerated the removal of rock materials from the developing cave-void until the base-level of the adjacent drainage was raised, at which time the slope angle between the drainage bottom of and the cave floor diminished to the point where the removal of the softer sandstone slowed down to an almost imperceptible amount. When this point in cave development was reached rock debris began to collect on the floor of the cave.

Today the floor of the cave is a combination of bedrock covered with soft sand, silt and clay sized particles that share space with blocks and pieces of sandstone that have fallen off the ceiling or been cast from the walls of the cave. Adding to this assortment of geologic refuse are bits and pieces of vegetative debris and dust that have been, in both cases, blown into the cave or in the case of the former, carried in by animals for, perhaps, use as nesting and/or bedding materials.

Second Question

Due to a lack of closely spaced radiocarbon dates, the annual rate of accumulation of materials within the cave is difficult to derive with any degree of precision. At present, there are only four points from which to draw conclusions regarding this question. Two of those points come from McLean's 1976 work and the other two from Fisher's 2008 investigation.

One of McLean's (1976:70-87) two samples came from a charcoal deposit in his excavation's Feature 3, this a fire-hearth exposed at a depth of 96-102 cm (38-40 in.) and dated at 580 ± 100 PB (Late Prehistoric); the other sample was obtained from a bison bone (deposit) encountered in Feature 5 located at a depth of 2.4 m (96 in.) below the surface, it was dated at 2100 ± 80 PB (Late Plains Archaic).

Fisher's (2010a:11) two dates came from the south wall of his 2008 Unit 2 excavation. One sample that was dated at 1,230 ± 40 PB (Late Prehistoric) came from a fire hearth at a depth of 92 cm (36 in.); and the other, dated at 1,950 ± 40 PB (Late Plains Archaic), was collected at a depth of 115 cm (45 in.) from a dense mixture of charcoal and sediment (Fisher 2010a:11).

Based on this limited available data, I calculated the annual sedimentation rate within the cave as being between 0.35 mm (0.02 in.) and 0.50 mm (0.02+ in.) per year. On a yearly basis, this is an almost imperceptible amount. But given the passage of thousands of years, even a rate this low adds up over time. Clearly, additional information is needed in order to calculate a more substantive and defendable annual rate of sedimentation.

Third Question

This question concerns the source or sources of sediment found within the cave. My participation in the 2010 and 2011 investigations plus a review of the findings of McLean's 1976 and Fisher's 2008 investigations demonstrate that the bulk of the material making up the cave floor sediments originated from within the cave itself. This materials includes grains of sandstone that were cast off the walls and ceiling by a process of grain-by-grain disintegration of the sandstone. The grains were joined by pieces and blocks of sandstone that represent large failures in sections of the cave's walls and ceiling.

Some of the finer fractions found in the sieve analysis, silts and clays, likely came from outside the cave. Some of these silt and clay fractions may have accompanied the water that trickled into the cave and blown into the cave by the winds. Wind borne sediments could have come from points near and far, from areas where the vegetative cover of the landscape had been significantly reduced by drought.

But, for the most part, the composition of the floor materials mimics that of the surrounding rock units.

Fourth Question

The fourth question asks what difference might exist between sediments found within the cave as opposed to those outside. An answer to this question is, in part, shared with that given for the Third Question. Again, the bulk of the sediment found within the cave comes from the surrounding sandstone units. Very little of the cave sediment is represented by materials that would have been introduced from outside the cave. Indeed, individually or collectively the percentage of fine fractions (very fine sand, silt and clay) in my sieve analysis exceeded 10% for only 5 of the 27 sample intervals.

By contrast, a soil texture analysis of Units 4 and 5 (2010 investigation) showed the fine-fraction component to classify out as either a Sandy loam or a Clay loam soil. This would suggest that these two units have received a large portion of their materials from the surrounding terrain which, in this area, consists of multiple thick and interbedded layers of siltstone, claystone, sandstone and coal.

Fifth Question

The nature of depositional variability across the cave is the fifth question. To recount, the sediment within the cave is a heterogeneous mixture of large and small pieces of the surrounding sandstone that has been diluted with a small fraction of external materials such as vegetative debris, windblown dust and silt and, as well, some silt and clay washed into the cave through cracks in its cap-rock unit.

The largest materials, blocks and slabs of sandstone, are seen along the south wall. However, every unit that has penetrated to the cave's basement floor has encountered large blocks and pieces of fallen wall and ceiling rock. The origins of the sand sized fractions, for the most part, are the wall and ceiling rocks.

The special distribution of the materials either blown or washed into the cave are hard to characterize without the benefit of doing a detailed sieve analysis, one considerable more extensive that the one recounted in this report. Such a study would involve a vertical sampling along a line stretching from the front of the cave to its back. Without doing so, it is impossible to know if such fine grained materials are evenly distributed across the floor or whether they are more abundant at the front or opening to the cave as opposed to some other area of the cave.

A close study of the profiles for Units 1, 2 and 3 indicates that the cave's basement floor slopes downward from its back to its front (opening) and downward from its north wall to its south wall. As a result, the sedimentary fill is thicker towards both its opening and its south wall side.

Vegetative debris found in the back of the cave, most likely, represents bedding materials brought into the cave by area animals such as coyotes, foxes, and rodents that have used the cave as a denning area. It is very likely that some of these materials could have been introduced by humans as well.

Potential Cultural History Value

In conclusion, it is important to note that all of the archaeological investigations so far conducted at Horseshoe Cave have affirmed the past use of this site. In addition, these studies not only document a use extends back almost 2,000 years and strongly suggest a site-use history that is much deeper in time. It is reasonable, therefore, to assume that additional investigative activity materially add to the cultural information already gathered from this site; information that has the potential to tell us even more about the pre-contact inhabitants of southeastern Montana and, as well, the past environment encountered by these early habitants. Therefore, I would be remiss in not recommending future investigative activities at Horseshoe Cave, activities that should employ some or all of the practices and technologies that I have suggested above.

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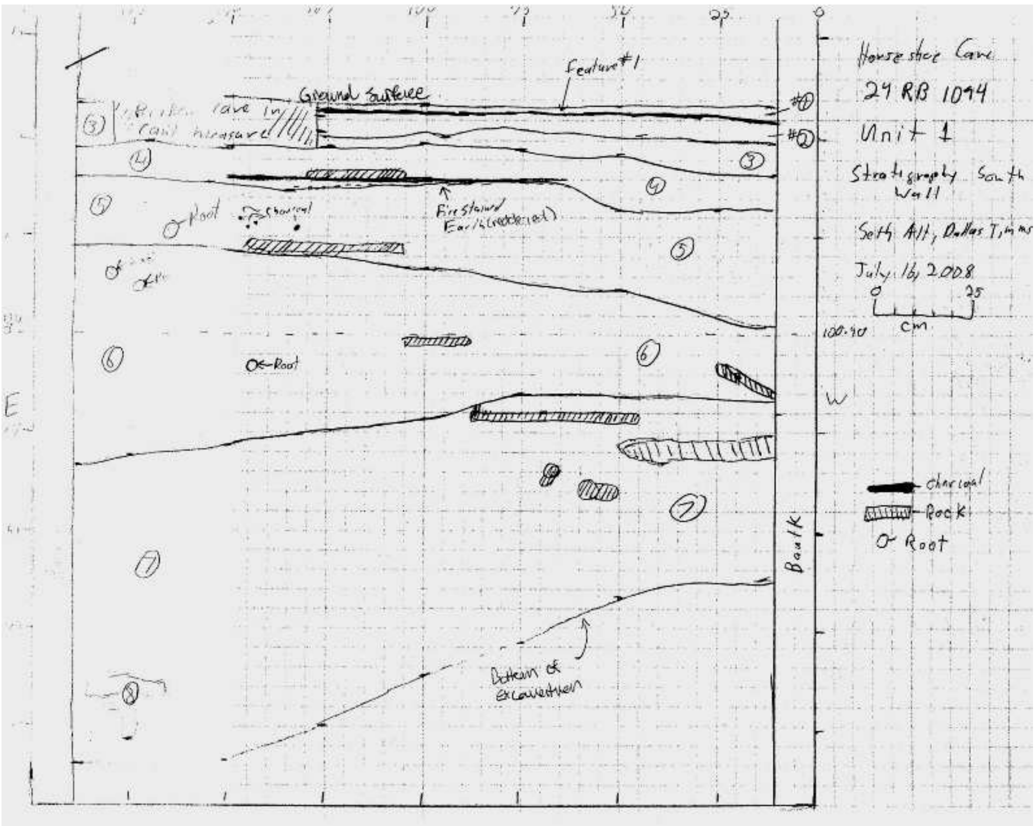
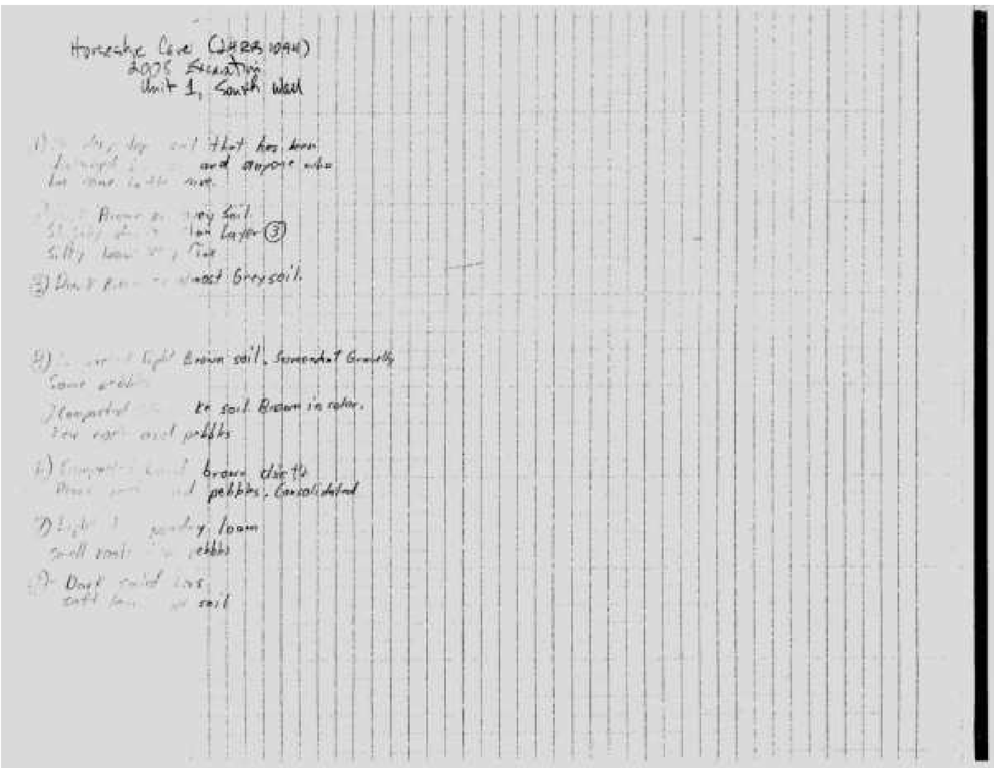
APPENDIX A

2008 Horseshoe Cave Investigation
Units 1 and 2 Profiles

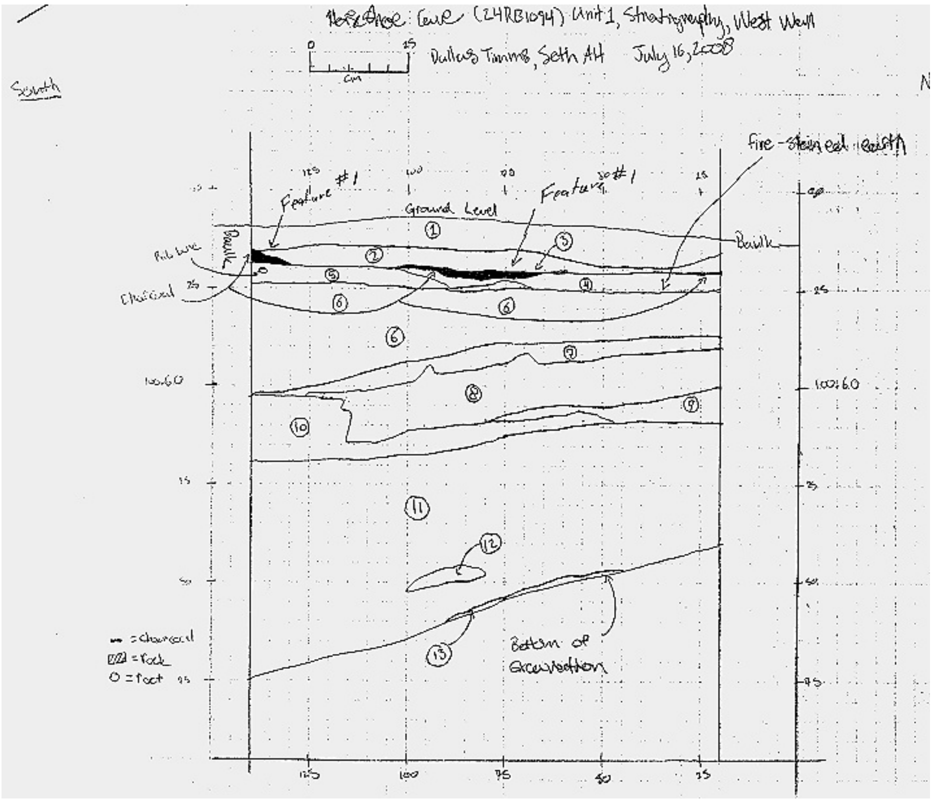
APPENDIX A

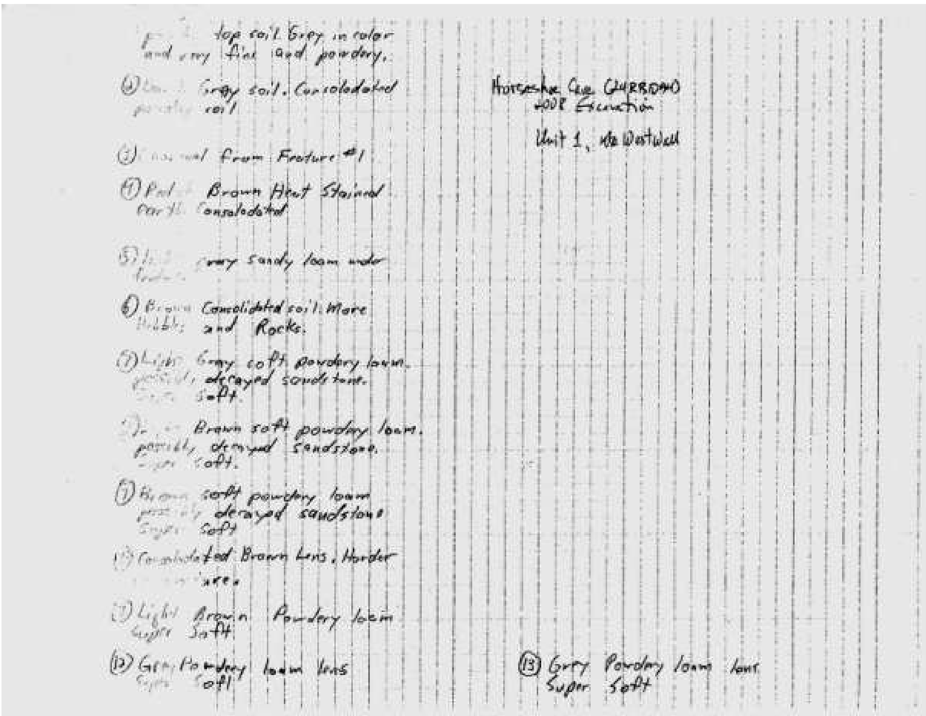
2008 Horseshoe Cave Investigation Units 1 and 2 Profiles





2008 Unit 1 South-wall profile and notes.




top soil Grey in color and very fine and powdery.

② Gray soil. Consolodated soil

③ from Feature #1

④ Pal Brown Heat Stained earth. Consolodated

⑤ Grey sandy loam under feature.

⑥ Brown Consolidated soil. More Rubble and Rocks.

⑦ Light Gray soft powdery loam. possibly decayed sandstone. Soft.

⑧ Brown soft powdery loam. possibly decayed sandstone. Super soft.

⑨ Brown soft powdery loam possibly decayed sandstone Super Soft

⑩ Consolidated Brown Lens. Harder area.

⑪ Light Brown Powdery loam Super Soft

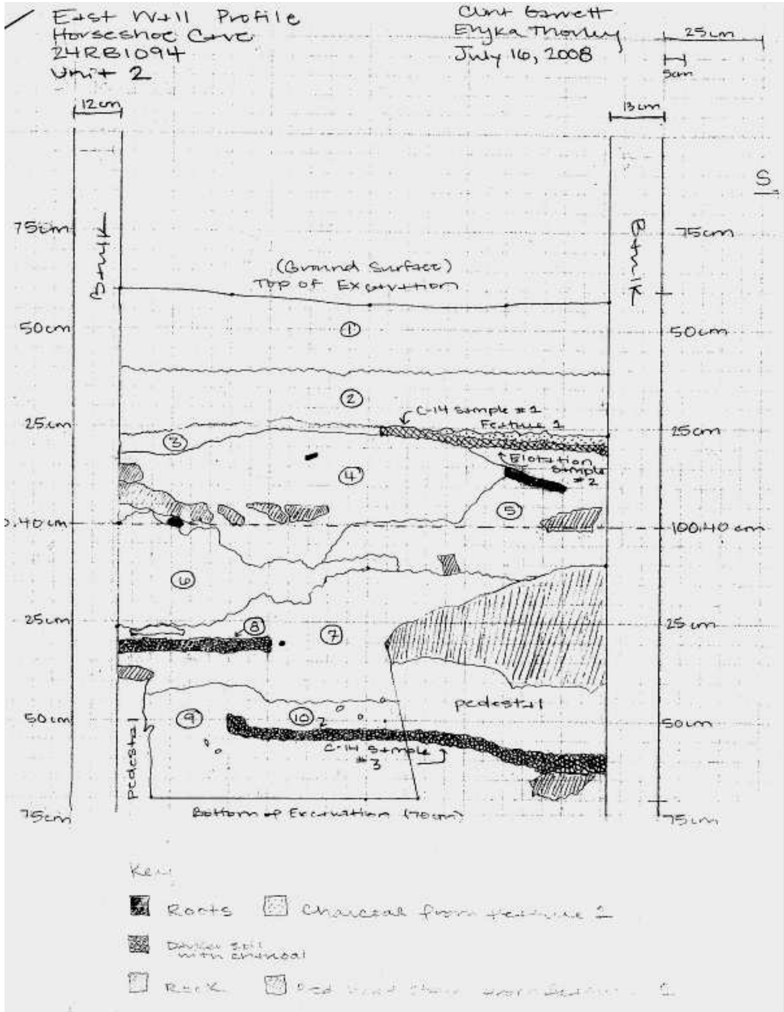
⑫ Grey Powdery loam lens Super Soft

Horseshoe Cave (24RB1094) 2008 Excavation

Unit 1, the West wall

⑬ Grey Powdery loam lens Super Soft

2008 Unit 1 West-wall profile and notes.



(1) [illegible] less than ½ cm in diameter.

(2) [illegible] lighter brown in color with coarse texture and pebbles up to [illegible] cm in diameter.

(3) Darker brown in color, fine grained silty sediment with no pebbles.

(4) Lighter in color than layer 3, cemented conglomerate with pebbles up to 5 cm. There be many small roots and well compacted.

(5) Color is darker than layer 4 but lighter than 3. Fine grained & cemented with very few pebbles all less than 1 cm in diameter. Homogenous in composition.

(6) Lightest layer in east wall both in color and texture. Fine grained silty loam with no pebbles. Possible decaying sandstone.

(7) Similar to layer 5 but with less pebbles. Less compacted than layer 5 but with similar color. Sporadic pebbles between 1–3 cm. Root holes are present.

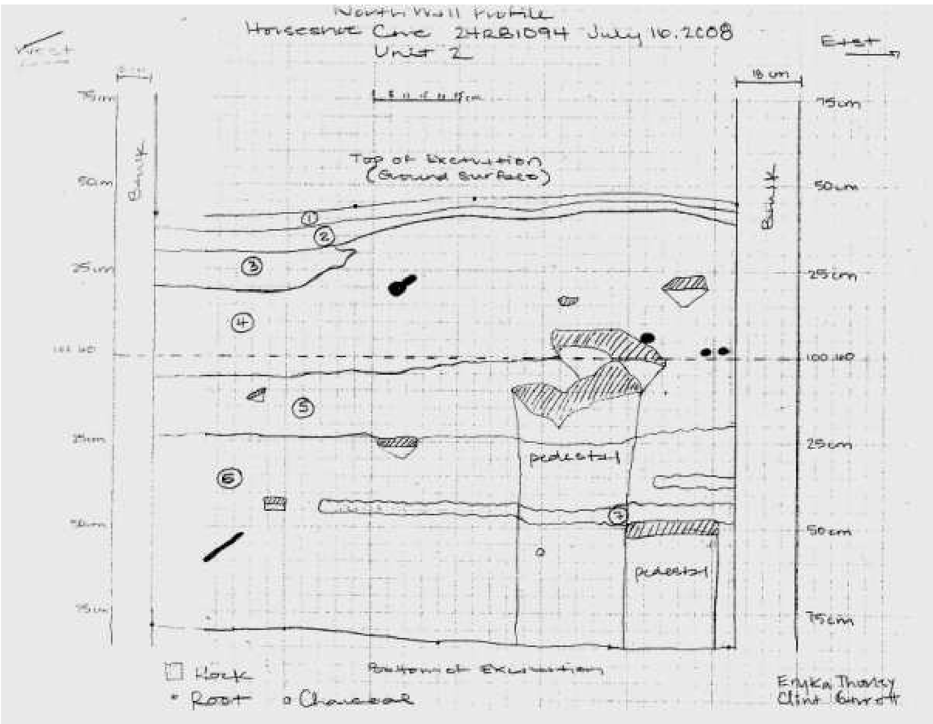
(8) Undesignated feature. Charcoal & soil staining present. No red heat stained earth. Charcoal fragments up to 1cm in diameter. 1cm thick layer of coarse pebbles up to 10cm in length near the top of the layer. Very distinguishable layer in the stratigraphy.

(9) Second lightest layer in comparison to layer 6. Very homogenous and compacted. Appears to be sandy loam but is darker than layer 6. Possible decaying sandstone?

(10) Undesignated feature where sample #3 was obtained. 5cm in thickness with charcoal fragments up to 2cm in diameter. Soil is dark brown but not heat stained.

Horseshoe Cave (24RB1094)
2008 Excavation
Unit 2, East Wall

2008 Unit 2 East-wall profile and notes.



Layer Descriptions

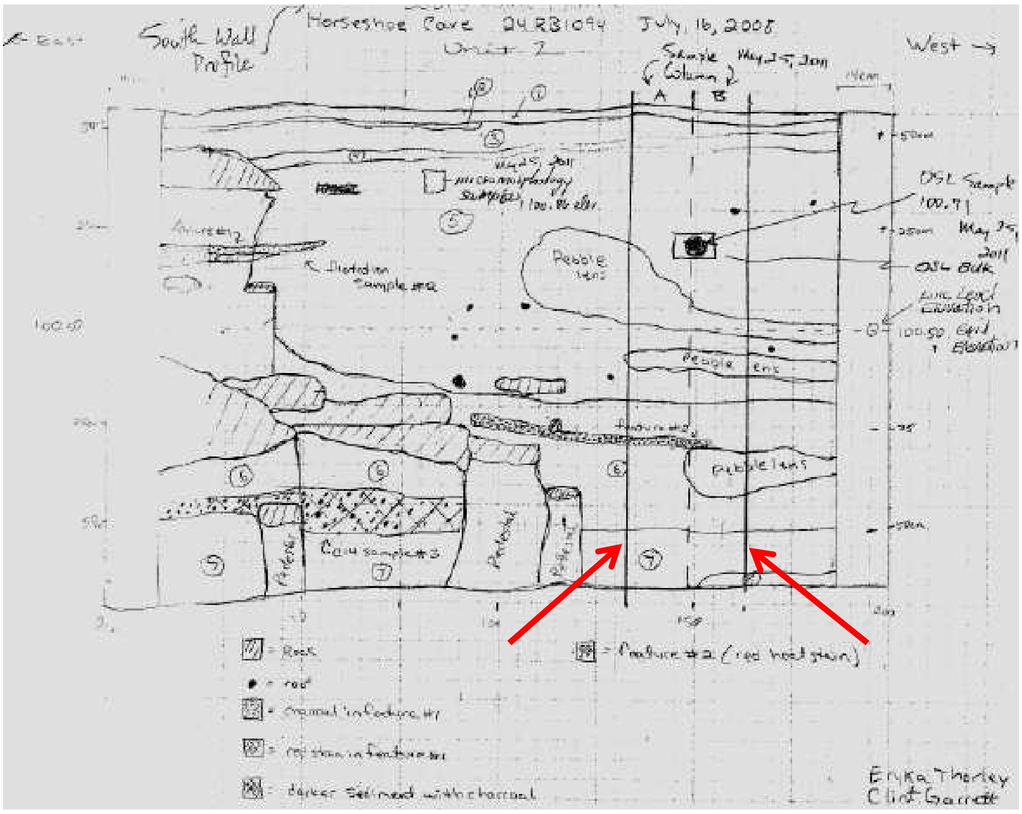
1. Loose [illegible] consolidated sand with 2 cm of top debris. Light brown in color.
2. Slightly darker in color than layer 1. Small pebbles up to ½ cm in diameter. Powdery loam.
3. [illegible] [illegible] brown sediment. Few pebbles measuring less than 2 cm in diameter. Finer grain size than layer 2.
4. Same [illegible] as sediment in layer 3. More compacted than layer 3 with pebbles up to 5 cm in diameter.
5. [illegible] thick rocky layer with rocks up to 15 cm in length. Heavily compacted with sporadic sandy lenses.
6. Lightest layer on North wall. Moist, homogenous, fine grained, no pebbles and lightest sand in color along the north wall. Many small rocks, possible decaying sandstone.
7. Darkest layer on north wall. Unconsolidated with many roots. [illegible] but heavily stained. Extends at same level into the [illegible]

Horseshoe Cave (24RB1094)

2008 Excavation

Unit 2, North Wall

2008 Unit 2 North-wall profile and notes.



Layer Descriptions

1. Unconsolidated sand with grass and pine needles.
2. 4 cm distinguishable grey layer of sediment. No pebbles and unconsolidated in composition.
3. Moist, unconsolidated sand with pebbles up to 1 cm in diameter.
4. Lighter in color than layer 3. More consolidated, finer grained sand with higher pebble concentration than layer 3.
5. Very compacted coarse grained sand with pebble lens extending into western portion of layer. Lighter brown sand similar in color to layer 4.
6. Homogeneous fine grained sand. Moist to the touch. Darkest layer in color on South Wall.
7. Lightest layer both in color and texture along South wall. Fine grained very homogenous sandy loam. Possible decaying sandstone.
8. Homogeneous, sticky, reddish brown sediment. No red heat stain or charcoal.

Horseshoe Cave (24RB1094)
2008 Excavation
Unit 2, South Wall

2008 Unit 2 South-wall profile and notes. Note area (red arrows) where column samples were taken in 2011 and Column B of the two columns collected analyzed for this report.

APPENDIX B

Horseshoe Cave Sieve Analysis Data Summary, and Sample-Interval Data Sheets

Horseshoe Cave Sieve Analysis Data Summary

Depth Below Surface (cm)	Sample Interval (cm)	Sample Weight (gm)	Standard Deviation	Median	Mean	Skew	Sorting	pH
0 to 5	+55 to +60	464.9	37.7	71.8	66.4	-0.5	2.1	8.0
5 to 10	+50 to +55	688.4	63.4	76.7	98.3	0.2	2.0	8.3
10 to 15	+45 to +50	743.6	72.5	76.6	106.2	1.0	1.8	8.1
15 to 20	+40 to +45	570.7	47.3	94.1	81.5	-0.6	2.3	8.4
20 to 25	+35 to +40	681.3	57.4	97.0	97.3	0.4	1.8	8.1
25 to 30	+30 to +35	786.5	71.0	108.3	112.4	0.0	2.3	8.2
30 to 35	+25 to +30	636.7	61.3	90.0	91.0	0.5	2.4	8.0
35 to 40	+20 to +25	664.9	42.6	121.3	95.0	-1.7	1.4	8.0
40 to 45	+15 to +20	653.2	54.6	106.9	93.3	-0.6	2.4	8.0
45 to 50	+10 to +15	956.7	80.1	155.5	136.7	-0.5	2.2	8.2
50 to 55	+5 to +10	676.4	63.0	102.6	96.6	0.2	2.3	8.3
55 to 60	0 to +5	422.3	35.7	67.7	60.3	-0.5	2.3	8.1
60 to 65	0 to -5	785.7	57.4	145.2	112.2	-0.9	1.7	8.0
65 to 70	-5 to -10	671.7	86.2	79.5	96.0	0.8	3.6	8.3
70 to 75	-10 to -15	808.2	88.8	92.2	115.5	1.3	2.2	8.4
75 to 80	-15 to -20	748.3	56.1	102.5	106.9	-0.2	1.5	8.5
80 to 85	-20 to -25	680.5	58.3	102.0	97.2	-0.4	2.0	8.5
85 to 90	-25 to -30	972.2	83.5	133.9	138.9	-0.1	2.0	8.6
90 to 95	-30 to -35	712.1	75.8	85.0	101.7	0.8	2.6	8.5
95 to 100	-35 to -40	685.8	89.0	63.6	98.0	1.1	2.7	8.5
100 to 105	-40 to -45	833.0	100.9	71.8	119.0	1.3	2.5	8.4
105 to 110	-45 to -50	1083.1	122.1	109.5	154.7	0.6	2.3	8.4
110 to 115	-50 to -55	522.9	93.9	13.6	74.7	1.5	10.9	8.4
115 to 120	-55 to -60	601.7	106.9	28.7	86.0	1.7	4.5	8.4
120 to 125	-60 to -65	570.6	76.2	29.6	81.5	0.4	4.4	8.3
125 to 130	-65 to -70	392.6	71.6	22.2	56.1	1.6	5.2	8.2
130 to 134	-70 to -74	531.5	60.6	56.6	75.9	0.8	2.6	8.1
	Average:	699.0	70.9			0.1	3.1	8.3
	Range:	392.6-1083.1	35.7-122.1			-1.7 to 1.7	1.4 to 10.9	8.0 to 8.6

Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

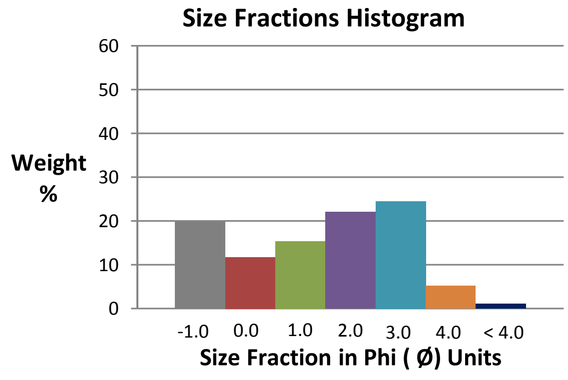
Sample Interval: +55 to +60 cm　　**Interval Depth Below Surface:** 0 to 5 cm

Stratum: 1

Date Collected: 05/25/2011　　**Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	92.0	20	Granule plus rock fragments	Charcoal (10 x 5 mm); sml roots & veg remains; ss granules/pebbles (15 x 10 mm to 2 mm); black carbon
18	1.00	0.0	54.6	12	Very coarse sand	Small charcoal pieces & rootlets; ss granules
35	0.50	1.0	71.8	15	Coarse sand	Charcoal; ss granules
60	0.25	2.0	102.9	22	Medium sand	Small grains anular to sub-angular
120	0.125	3.0	114.2	25	Fine sand	Grains angular to sub-angular
230	0.0625	4.0	24.1	5	Very fine sand	Grains angular to sub-angular
<230	<0.0625	<4	5.3	1	Silt/Clay	

Total Sample Weight:	464.9
Standard Deviation:	37.7
Median:	71.8
Mean:	66.4
Skew:	-0.5
Sorting:	2.1



Interval Munsell Color:

Wet: 10YR 5/3 brown

Dry: 10YR 7/3 very pale brown

Interval pH: 8.0

Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

Sample Interval: +50 to +55 cm

Interval Depth Below Surface: 5 to 10 cm

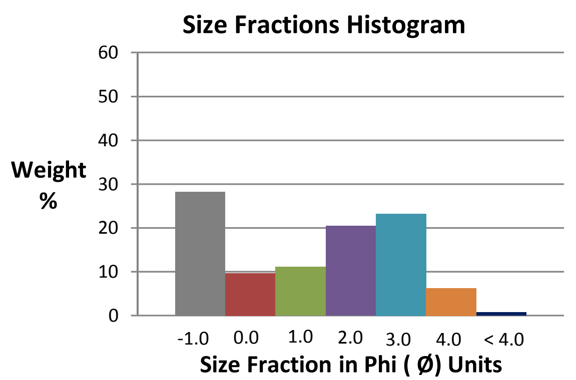
Stratum: 3

Date Collected: 05/25/2011

Collected By: Jack Fisher and Norman Smyers

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	195.1	28	Granule plus rock fragments	Large pieces of wall and ceiling rock (>10 mm); charcoal bound grains; vegative pieces
18	1.00	0.0	66.6	10	Very coarse sand	Aggregates of grains; vegative debris; charcoal; individual grains angular to sub-angular
35	0.50	1.0	76.7	11	Coarse sand	Aggregates of grains; vegative debris; charcoal; individual grains angular to sub-angular
60	0.25	2.0	141.1	20	Medium sand	Aggregates of grains; vegative debris; charcoal; individual grains angular to sub-angular
120	0.125	3.0	160.2	23	Fine sand	Grains angular to sub-angular
230	0.0625	4.0	43.4	6	Very fine sand	Grains angular to sub-angular
<230	<0.0625	<4	5.3	1	Silt/Clay	Grains angular to sub-angular

Total Sample Weight:	688.4
Standard Deviation:	63.4
Median:	76.7
Mean:	98.3
Skew:	0.2
Sorting:	2.0



Interval Munsell Color:

Wet: 10YR 5/4 yellowish brown

Dry: 10YR 7/2 light gray

Interval pH: 8.3

Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

Sample Interval: +45 to +50 cm **Interval Depth Below Surface:** 10 to 15 cm

Stratum: 4

Date Collected: 05/25/2011 **Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	168.6	23	Granule plus rock fragments	Small pieces charcoal; vegative debris; ceiling & wall rock debris (10-15 mm diameter)
18	1.00	0.0	62.8	8	Very coarse sand	Small pieces charcoal; vegative debris; round clusters of individual grains
35	0.50	1.0	76.6	10	Coarse sand	Small pieces charcoal; vegative debris; round clusters of individual grains
60	0.25	2.0	113.6	15	Medium sand	Charcoal; vegative debris; grain clusters; grains angular to sub-angular
120	0.125	3.0	246.7	33	Fine sand	Grains angular to sub-angular
230	0.0625	4.0	59.1	8	Very fine sand	Grains angular to sub-rounded
<230	<0.0625	<4	16.2	2	Silt/Clay	Discernable grains angular to sub-angular

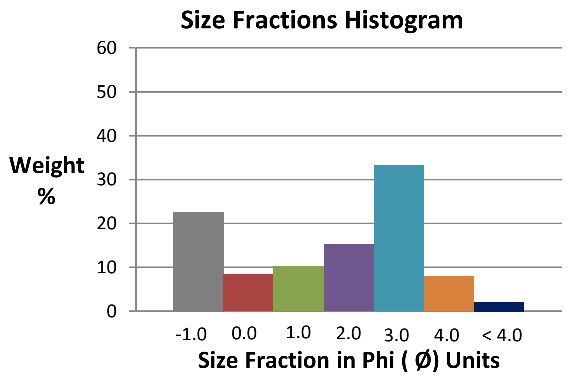
Total Sample Weight:	743.6
Standard Deviation:	72.5
Median:	76.6
Mean:	106.2
Skew:	1.0
Sorting:	1.8

Interval Munsell Color:

Wet: 7.5YR 4/2 brown

Dry: 10YR 6/2 light brownish gray

Interval pH: 8.1



Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

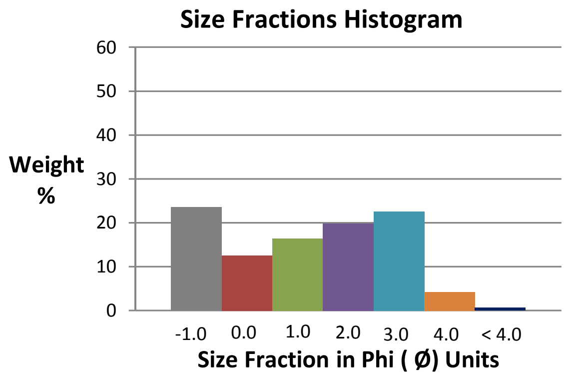
Sample Interval: +40 to +45 cm **Interval Depth Below Surface:** 15 to 20 cm

Stratum: 4

Date Collected: 05/25/2011 **Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	134.6	24	Granule plus rock fragments	Pebble sized pieces wall & ceiling ss (up to 10 mm in diameter)
18	1.00	0.0	71.5	13	Very coarse sand	Grain clusters; small amt. vegetation debris
35	0.50	1.0	94.1	16	Coarse sand	Grain clusters; individual grains angular to sub-angular
60	0.25	2.0	113.4	20	Medium sand	Charcoal; grain clusters; individual grains angular to sub-angular
120	0.125	3.0	129.1	23	Fine sand	A few grain clusters; individual grains angular to sub-angular
230	0.0625	4.0	24.0	4	Very fine sand	Grains angular to sub-angular
<230	<0.0625	<4	4.0	1	Silt/Clay	Discernable individual grains angular to sub-rounded

Total Sample Weight:	570.7
Standard Deviation:	47.3
Median:	94.1
Mean:	81.5
Skew:	-0.6
Sorting:	2.3



Interval Munsell Color:

Wet: 10YR 4/3 brown

Dry: 10YR 5/4 yellowish brown

Interval pH: 8.4

Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

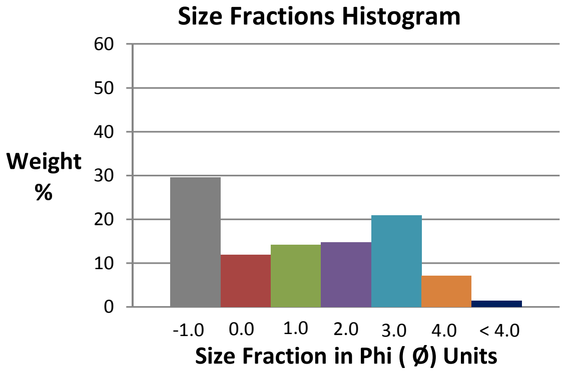
Sample Interval: +35 to +40 cm **Interval Depth Below Surface:** 20 to 25 cm

Stratum: 5

Date Collected: 05/25/2011 **Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	201.3	30	Granule plus rock fragments	Wall & ceiling rock 10 mm in diameter; rounded grain clusters 2-5 mm in diameter
18	1.00	0.0	81.4	12	Very coarse sand	Rounded grain clusters 1-2 mm in diameter; a few small pieces of wall and ceiling rock
35	0.50	1.0	97.0	14	Coarse sand	Charcoal/vegetative debris; grain clusters; grains angular to sub-angular with some exhbiting frosting
60	0.25	2.0	100.2	15	Medium sand	Charcoal; grain clusters; grains angular to sub-angular with some exhbiting frosting
120	0.125	3.0	142.4	21	Fine sand	Grains angular to sub-angular with some exhbiting frosting
230	0.0625	4.0	48.9	7	Very fine sand	Grains angular to sub-angular with some exhbiting moderate to high degree of frosting
<230	<0.0625	<4	10.1	1	Silt/Clay	Discernable grains angular to sub-angular

Total Sample Weight:	681.3
Standard Deviation:	57.4
Median:	97.0
Mean:	97.3
Skew:	0.4
Sorting:	1.8



Interval Munsell Color:

Wet: 7.5YR 4/4 brown

Dry: 10YR 5/6 yellowish brown

Interval pH: 8.1

Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

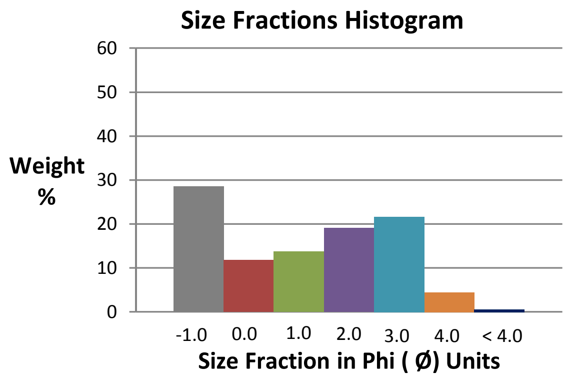
Sample Interval: +30 to +35 cm **Interval Depth Below Surface:** 25 to 30 cm

Stratum: 5

Date Collected: 05/25/2011 **Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	224.4	29	Granule plus rock fragments	Wall & ceiling rock pieced 5-9 mm in diameter; burnt shale flake; smaller frctions grain clusters
18	1.00	0.0	93.0	12	Very coarse sand	Vegetative debris & rootlets; equal amnts. Of wall/ceiling rock & grain clusters
35	0.50	1.0	108.3	14	Coarse sand	Grain clusters; individual grains angular to sub-angular with some exhibiting frosting
60	0.25	2.0	150.5	19	Medium sand	A few grain clusters; individual grains angular to sub-angular with some exhibiting frosting
120	0.125	3.0	170.4	22	Fine sand	Grains angular to sub-angular with some frosting
230	0.0625	4.0	35.0	4	Very fine sand	Grains angular to sub-angular with some frosting
<230	<0.0625	<4	4.9	1	Silt/Clay	Discernable grains angular to sub-rounded with some exhibiting frosting

Total Sample Weight:	786.5
Standard Deviation:	71.0
Median:	108.3
Mean:	112.4
Skew:	0.0
Sorting:	2.3



Interval Munsell Color:

Wet: 7.5YR 4/6 strong brown

Dry: 10YR 5/4 yellowish brown

Interval pH: 8.2

Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

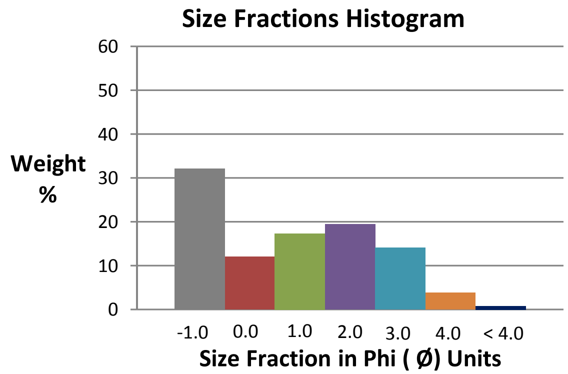
Sample Interval: +25 to +30 cm **Interval Depth Below Surface:** 30 to 35 cm

Stratum: 5

Date Collected: 05/25/2011 **Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	204.5	32	Granule plus rock fragments	Wall & ceiling rock pieced 5-9 mm in diameter; burnt shale flake; smaller frctions grain clusters
18	1.00	0.0	76.7	12	Very coarse sand	Small amount vegetative debris; bulk of fraction composed of grain clusters
35	0.50	1.0	110.9	17	Coarse sand	A large portion of fraction composed of grain clusters, grains angular to sub-rounded
60	0.25	2.0	124.4	20	Medium sand	A large portion of fraction composed of grain clusters, grains angular to sub-rounded
120	0.125	3.0	90.0	14	Fine sand	Grains angular to sub-rounded with some exhibiting frosting
230	0.0625	4.0	25.0	4	Very fine sand	Grains angular to sub-rounded with most exhibiting frosting
<230	<0.0625	<4	5.2	1	Silt/Clay	Grains angular to sub-rounded with about half exhibiting frosting

Total Sample Weight:	636.7
Standard Deviation:	61.3
Median:	90.0
Mean:	91.0
Skew:	0.5
Sorting:	2.4



Interval Munsell Color:

Wet: 10YR 4/5 yellowish brown

Dry: 10YR 6/4 brownish yellow

Interval pH: 8.0

Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

Sample Interval: +20 to +25 cm | **Interval Depth Below Surface:** 35 to 40 cm

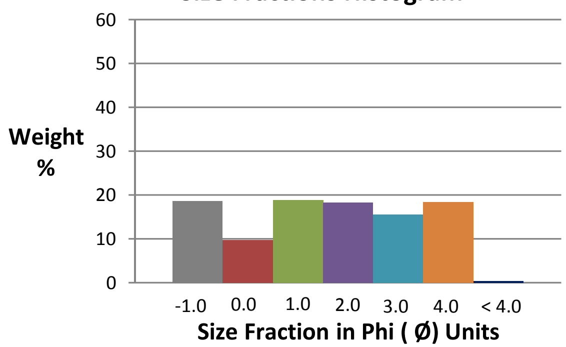
Stratum: 5

Date Collected: 05/25/2011 | **Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	124.1	19	Granule plus rock fragments	Granules (10 mm diameter) disintirated wall & roof rock; vegetative debris (rootlets, etc.)
18	1.00	0.0	64.8	10	Very coarse sand	Granules disintirated wall & roof rock; vegetative debris (rootlets, etc.)
35	0.50	1.0	125.6	19	Coarse sand	Granules disintirated wall & roof rock; vegetative debris (rootlets, etc.)
60	0.25	2.0	121.3	18	Medium sand	Granules; vegetative debris
120	0.125	3.0	103.9	16	Fine sand	Grains angular to sub-angular
230	0.0625	4.0	122.3	18	Very fine sand	Grains angular to sub-angular
<230	<0.0625	<4	2.9	0	Silt/Clay	Grains angular to sub-angular

Total Sample Weight:	664.9
Standard Deviation:	42.6
Median:	121.3
Mean:	95.0
Skew:	-1.7
Sorting:	1.4

Size Fractions Histogram



Interval Munsell Color:

Wet: 10YR 5/3 brown

Dry: 10YR 6/4 brownish yellow

Interval pH: 8.0

Horseshoe Cave (24RB1094) Sieve Analysis

(South Wall Unit 2, Column B)

Sample Interval: +15 to +20 cm **Interval Depth Below Surface:** 40 to 45 cm

Stratum: 5

Date Collected: 05/25/2011 **Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	144.6	22	Granule plus rock fragments	Granules (1-10 mm diameter) disintigrated wall/roof rock; vegetative debris
18	1.00	0.0	79.4	12	Very coarse sand	Granules disintigrated wall/roof rock; vegetative debris
35	0.50	1.0	133.3	20	Coarse sand	Granules disintigrated wall/roof rock; vegetative debris
60	0.25	2.0	157.2	24	Medium sand	Small granules & individual grains (angular to sub-angular)
120	0.125	3.0	106.9	16	Fine sand	Individual grains (angular to sub-angular)
230	0.0625	4.0	26.5	4	Very fine sand	Grains (angular to sub-angular) with some frosting
<230	<0.0625	<4	5.3	1	Silt/Clay	Grains (angular to sub-rounded)

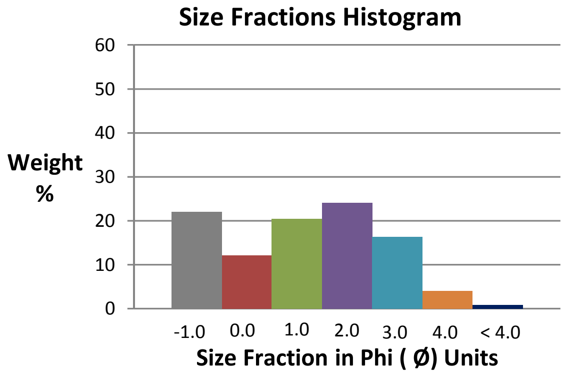
Total Sample Weight:	653.2
Standard Deviation:	54.6
Median:	106.9
Mean:	93.3
Skew:	-0.6
Sorting:	2.4

Interval Munsell Color:

Wet: 10YR 5/4 yellowish brown

Dry: 7.5YR 5.5/4 light brown

Interval pH: 8.0



Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

Sample Interval: +10 to +15 cm **Interval Depth Below Surface:** 45 to 50 cm

Stratum: 5

Date Collected: 05/25/2011 **Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	212.0	22	Granule plus rock fragments	Large pieces (10-30 mm) wall/ceiling ss & vegetative debris & charcoal
18	1.00	0.0	103.7	11	Very coarse sand	Sandstone granules & vegetative debris (rootlets/small branchlets); charcoal
35	0.50	1.0	155.5	16	Coarse sand	Sandstone granules & vegetative debris (rootlets/small branchlets); charcoal
60	0.25	2.0	224.9	24	Medium sand	Granules; vegetative debris; charcoal; individual grains angular to sub-angular
120	0.125	3.0	207.6	22	Fine sand	Vegetative debris; charcoal; individual grains angular to sub-angular
230	0.0625	4.0	45.2	5	Very fine sand	Some vegetative debris; grains angular to sub-angular w/no apparent frosting
<230	<0.0625	<4	7.8	1	Silt/Clay	Grains angular to sub-angular

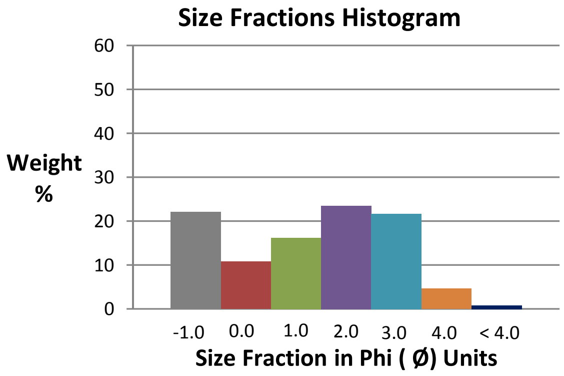
Total Sample Weight:	956.7
Standard Deviation:	80.1
Median:	155.5
Mean:	136.7
Skew:	-0.5
Sorting:	2.2

Interval Munsell Color:

Wet: 7.5YR 5/3 brown

Dry: 10YR 6.5/2 light brownish gray

Interval pH: 8.2



Horseshoe Cave (24RB1094) Sieve Analysis

(South Wall Unit 2, Column B)

Sample Interval: +5 to +10 cm

Interval Depth Below Surface: 50 to 55 cm

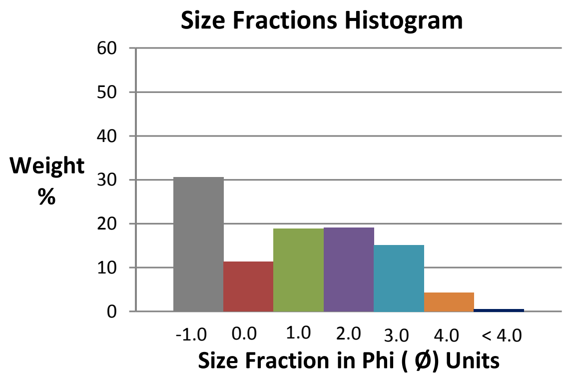
Stratum: 5

Date Collected: 05/25/2011

Collected By: Jack Fisher and Norman Smyers

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	206.8	31	Granule plus rock fragments	Granules (8-11 mm diameter) wall/ceiling rock; some vegetative debris
18	1.00	0.0	76.9	11	Very coarse sand	Granules wall/ceiling rock; vegetative debris
35	0.50	1.0	127.8	19	Coarse sand	Granules; vegetative debris
60	0.25	2.0	129.2	19	Medium sand	Granules; vegetative debris
120	0.125	3.0	102.6	15	Fine sand	Granules & individual grains (angular to sub-angular)
230	0.0625	4.0	29.2	4	Very fine sand	Granules & individual grains (angular to sub-angular)
<230	<0.0625	<4	3.9	1	Silt/Clay	Grains angular to sub-angular

Total Sample Weight:	676.4
Standard Deviation:	63.0
Median:	102.6
Mean:	96.6
Skew:	0.2
Sorting:	2.3



Interval Munsell Color:

Wet: 10YR 4/4 dark yellowish brown

Dry: 10YR 5.5/3 pale brown

Interval pH: 8.3

Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

Sample Interval: 0 to +5 cm

Interval Depth Below Surface: 55 to 60 cm

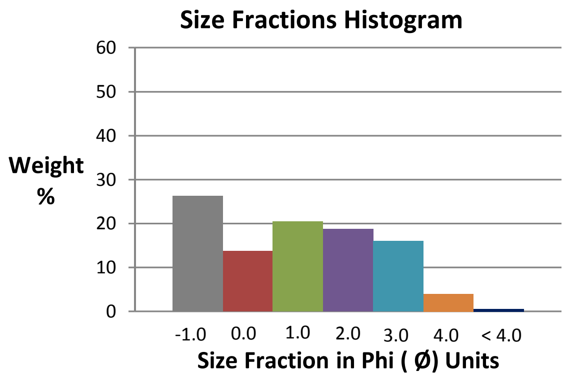
Stratum: Pebble lens

Date Collected: 05/25/2011

Collected By: Jack Fisher and Norman Smyers

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	111.0	26	Granule plus rock fragments	Wall/ceiling rock pieces 7-15 mm in size; some rounded pebbles 5-8 mm in diameter
18	1.00	0.0	58.4	14	Very coarse sand	Sandstone granules; vegetative debris
35	0.50	1.0	86.6	21	Coarse sand	Sandstone granules; vegetative debris
60	0.25	2.0	79.2	19	Medium sand	Sandstone granules; vegetative debris; individual grains angular to sub-angular
120	0.125	3.0	67.7	16	Fine sand	Some vegetative debris; grains angular to sub-angular with quartz somewhat frosted
230	0.0625	4.0	17.0	4	Very fine sand	Grains angular to sub-angular with quartz somewhat frosted
<230	<0.0625	<4	2.4	1	Silt/Clay	Grains angular to sub-angular; no apparent frosting of quartz grains

Total Sample Weight:	422.3
Standard Deviation:	35.7
Median:	67.7
Mean:	60.3
Skew:	-0.5
Sorting:	2.3



Interval Munsell Color:

Wet: 10YR 6.5/3 light yellowish brown

Dry: 7.5YR 4/3 brown

Interval pH: 8.1

Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

Sample Interval: 0 to -5 cm **Interval Depth Below Surface:** 60 to 65 cm

Stratum: Pebble lens

Date Collected: 05/25/2011 **Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	175.8	22	Granule plus rock fragments	Range of large sandstone pieces 10-40 mm in length w/most smaller; vegetative debris
18	1.00	0.0	94.4	12	Very coarse sand	Sandstone granules; vegetative debris
35	0.50	1.0	145.2	18	Coarse sand	Sandstone granules; vegetative debris
60	0.25	2.0	147.8	19	Medium sand	Small sandstone granules; individual grains angular to sub-rounded; quartz grains frosted
120	0.125	3.0	159.4	20	Fine sand	Grain clusters; individual grains angular to sub-rounded; some quartz grains frosted
230	0.0625	4.0	54.9	7	Very fine sand	Grains angular to sub-rounded; some quartz grains frosted
<230	<0.0625	<4	8.2	1	Silt/Clay	Grains angular to sub-rounded; some quartz grains frosted

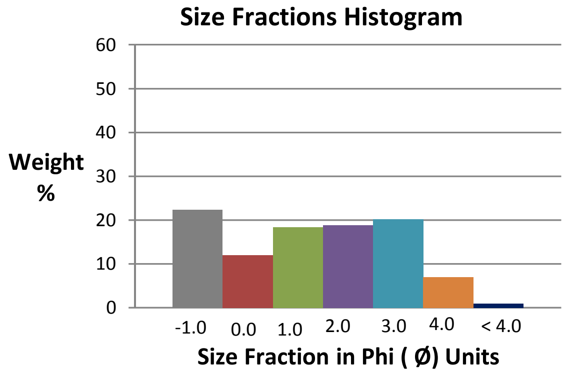
Total Sample Weight:	785.7
Standard Deviation:	57.4
Median:	145.2
Mean:	112.2
Skew:	-0.9
Sorting:	1.7

Interval Munsell Color:

Wet: 7.5YR 5/2 brown

Dry: 10YR 6.5/4 light yellowish brown

Interval pH: 8.0



Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

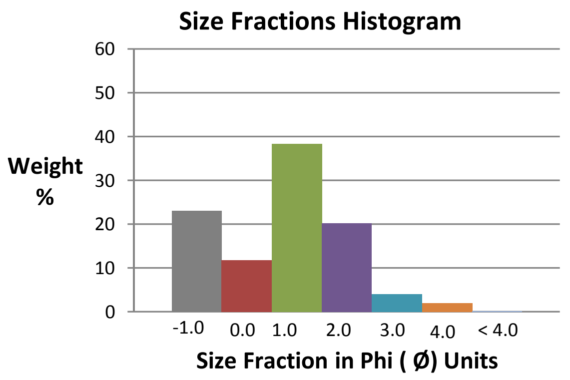
Sample Interval: -5 to -10 cm **Interval Depth Below Surface:** 65 to 70 cm

Stratum: 5

Date Collected: 05/25/2011 **Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	155.6	23	Granule plus rock fragments	Sandstone pieces of wall/ceiling rock; vegetative debris
18	1.00	0.0	79.5	12	Very coarse sand	Sandstone granules; a few pieces of red baked shale; some vegetative debris
35	0.50	1.0	257.7	38	Coarse sand	Grain clusters; some vegetative debris; individual grains angular to sub-angular
60	0.25	2.0	136.4	20	Medium sand	Grains angular to sub-angular
120	0.125	3.0	27.8	4	Fine sand	Grains angular to sub-angular; some frosting of quartz grains
230	0.0625	4.0	13.6	2	Very fine sand	Grains angular to sub-angular; frosting of quartz grains common
<230	<0.0625	<4	1.1	0	Silt/Clay	Grains angular to sub-rounded; little frosting of quartz grains common

Total Sample Weight:	671.7
Standard Deviation:	86.2
Median:	79.5
Mean:	96.0
Skew:	0.8
Sorting:	3.6



Interval Munsell Color:

Wet: 7.5YR 4/2 brown

Dry: 10YR 5/4 dark yellowish brown

Interval pH: 8.3

Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

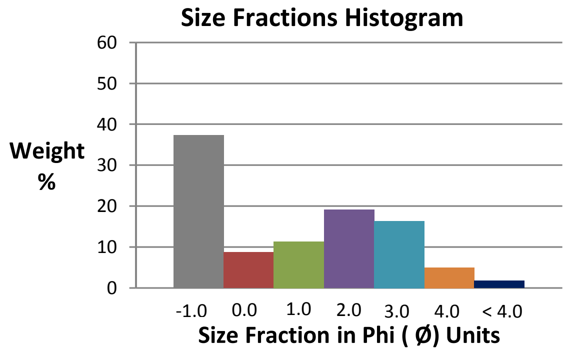
Sample Interval: -10 to -15 cm **Interval Depth Below Surface:** 70 to 75 cm

Stratum: Pebble Lens

Date Collected: 05/25/2011 **Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	302.5	37	Granule plus rock fragments	Large (10-25 mm) sandstone pieces of wall/ceiling rock; some vegetative debris
18	1.00	0.0	70.7	9	Very coarse sand	Sandstone granules; vegetative debris
35	0.50	1.0	92.2	11	Coarse sand	Sandstone granules; vegetative debris; some pieces red baked shale
60	0.25	2.0	154.8	19	Medium sand	Grain clusters; some vegetative debris; individual grains angular to sub-angular
120	0.125	3.0	132.8	16	Fine sand	Grain clusters; individual grains angular to sub-angular
230	0.0625	4.0	40.9	5	Very fine sand	Grains angular to sub-angular
<230	<0.0625	<4	14.3	2	Silt/Clay	Grains angular to sub-angular

Total Sample Weight:	808.2
Standard Deviation:	88.8
Median:	92.2
Mean:	115.5
Skew:	1.3
Sorting:	2.2



Interval Munsell Color:

Wet: 7.5YR 5/3 brown

Dry: 10YR 6.5/4 ligh yellowish brown

Interval pH: 8.4

Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

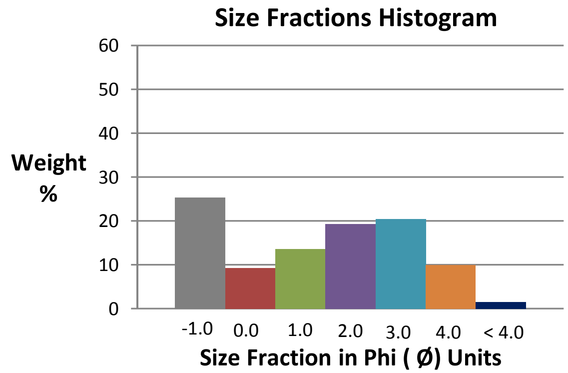
Sample Interval: -15 to -20 cm **Interval Depth Below Surface:** 75 to 80 cm

Stratum: 5

Date Collected: 05/25/2011 **Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	190.1	25	Granule plus rock fragments	One large stone 65 x 55 x 25 mm; rest smaller pieces of ss wall/ceiling rock
18	1.00	0.0	69.8	9	Very coarse sand	Granules of wall & ceiling rock; vegetative debris
35	0.50	1.0	102.5	14	Coarse sand	Granules of wall & ceiling rock; little vegetative debris
60	0.25	2.0	145.1	19	Medium sand	Small grain clusters; individual grains angular to sub-angular
120	0.125	3.0	153.8	21	Fine sand	A few grains clusters; individual grains angular to sub-angular
230	0.0625	4.0	75.1	10	Very fine sand	Grains angular to sub-angular; little frosting
<230	<0.0625	<4	11.9	2	Silt/Clay	Grains angular to sub-rounded; little frosting

Total Sample Weight:	748.3
Standard Deviation:	56.1
Median:	102.5
Mean:	106.9
Skew:	-0.2
Sorting:	1.5



Interval Munsell Color:

Wet: 7.5YR 5/3 brown

Dry: 10YR 6.5/4 light yellowish brown

Interval pH: 8.5

Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

Sample Interval: -20 to -25 cm **Interval Depth Below Surface:** 80 to 85 cm

Stratum: 6

Date Collected: 05/25/2011 **Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	157.3	23	Granule plus rock fragments	Wall/ceiling rock pieces up to 20 mm long; vegetative debris
18	1.00	0.0	65.4	10	Very coarse sand	Sandstone granules; vegetative debris; few flakes red-maroon burnt shale
35	0.50	1.0	102.0	15	Coarse sand	Sandstone granules; vegetative debris; charcoal
60	0.25	2.0	155.0	23	Medium sand	Sandstone granules; individual grains angular to sub-angular: some quartz grains frosted; vegetative debris
120	0.125	3.0	37.6	6	Fine sand	Sandstone granules; individual grains angular to sub-angular; some quartz grains frosted
230	0.0625	4.0	158.2	23	Very fine sand	Grains angular to sub-angular; some quartz grains frosted
<230	<0.0625	<4	5.0	1	Silt/Clay	Grains angular to sub-angular; less frosting of quartz grains

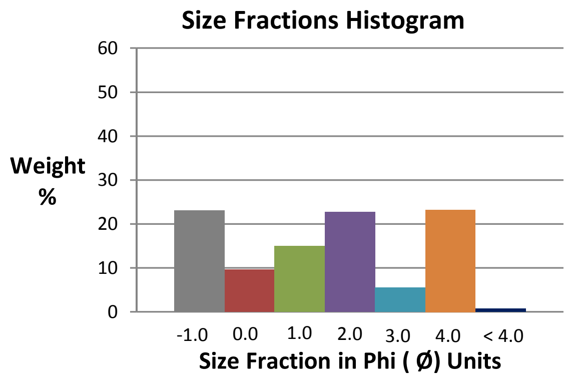
Total Sample Weight:	680.5
Standard Deviation:	58.3
Median:	102.0
Mean:	97.2
Skew:	-0.4
Sorting:	2.0

Interval Munsell Color:

Wet: 10YR 5/4 yellowish brown

Dry: 10YR 6.5/3 pale brown

Interval pH: 8.5



Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

Sample Interval: -25 to -30 cm **Interval Depth Below Surface:** 85 to 90 cm

Stratum: 6

Date Collected: 05/25/2011 **Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	204.1	21	Granule plus rock fragments	Wall/ceiling sandstone pieces up to 15 mm long; vegetative debris ; coal
18	1.00	0.0	85.6	9	Very coarse sand	Sandstone granules; maroon burnt shale; vegetative debris; coal
35	0.50	1.0	133.9	14	Coarse sand	Sandstone granules; vegetative debris
60	0.25	2.0	244.9	25	Medium sand	Sandstone granules; maroon burnt shale; vegetative debris; coal; grains angular to sub-angular
120	0.125	3.0	231.3	24	Fine sand	Grains angular to sub-angular
230	0.0625	4.0	56.7	6	Very fine sand	Grains angular to sub-angular; some frosting of quartz grains
<230	<0.0625	<4	15.7	2	Silt/Clay	Grains angular to sub-angular; some frosting of quartz grains

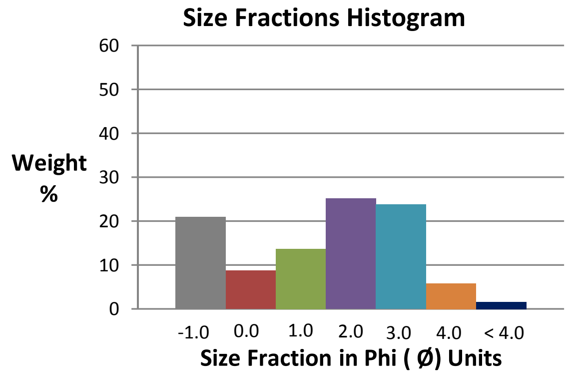
Total Sample Weight:	972.2
Standard Deviation:	83.5
Median:	133.9
Mean:	138.9
Skew:	-0.1
Sorting:	2.0

Interval Munsell Color:

Wet: 10YR 5/3 brown

Dry: 10YR 6.5/3 pale brown

Interval pH: 8.6



Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

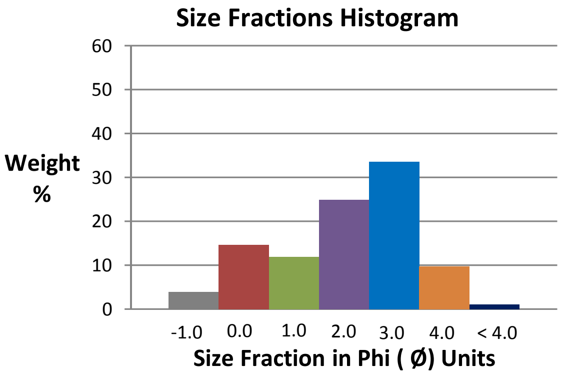
Sample Interval: -30 to -35 cm **Interval Depth Below Surface:** 90 to 95 cm

Stratum: Pebble lens

Date Collected: 05/25/2011 **Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	28.4	4	Granule plus rock fragments	Wall/ceiling rock pieces up to 35 mm long; burnt shale; vegetatine debris
18	1.00	0.0	104.5	15	Very coarse sand	Sandstone granules; vegetative debris; coal
35	0.50	1.0	85.0	12	Coarse sand	Sandstone granules; vegetative debris; coal
60	0.25	2.0	177.5	25	Medium sand	Sandstone granules; coal; individual grains angular to sub-angular
120	0.125	3.0	239.4	34	Fine sand	Grains angular to sub-angular; some frosting of quartz grains
230	0.0625	4.0	69.3	10	Very fine sand	Grains angular to sub-angular; some frosting of quartz grains
<230	<0.0625	<4	8.0	1	Silt/Clay	Grains angular to sub-angular; little frosting of quartz grains

Total Sample Weight:	712.1
Standard Deviation:	75.8
Median:	85.0
Mean:	101.7
Skew:	0.8
Sorting:	2.6



Interval Munsell Color:

Wet: 7.5YR 4/2 brown

Dry: 10YR 6/3 pale brown

Interval pH: 8.5

Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

Sample Interval: -35 to -40 cm **Interval Depth Below Surface:** 95 to 100 cm

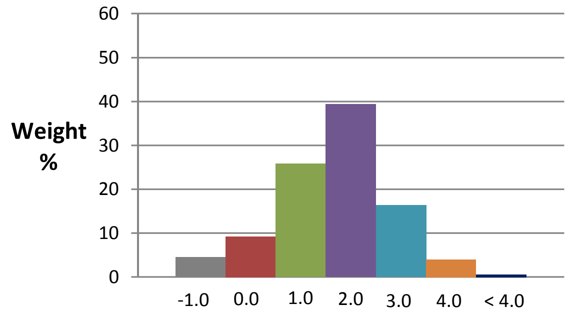
Stratum: Pebble lens

Date Collected: 05/25/2011 **Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	31.3	5	Granule plus rock fragments	Wall/ceiling rock pieces up to 35 mm long; vegetative debris; coal
18	1.00	0.0	63.6	9	Very coarse sand	Sandstone granules; vegetative debris; coal
35	0.50	1.0	177.2	26	Coarse sand	Sandstone granules; vegetative debris; coal
60	0.25	2.0	270.1	39	Medium sand	Sandstone granules; coal; individual grains angular to sub-angular
120	0.125	3.0	111.9	16	Fine sand	Grain clusters; coal; individual grains angular to sub-angular
230	0.0625	4.0	27.4	4	Very fine sand	Grains angular to sub-angular; only moderate frosting of quartz grains
<230	<0.0625	<4	4.3	1	Silt/Clay	Grains angular to sub-angular; little frosting of quartz grains

Total Sample Weight:	685.8
Standard Deviation:	89.0
Median:	63.6
Mean:	98.0
Skew:	1.1
Sorting:	2.7

Size Fractions Histogram



Interval Munsell Color:

Wet: 10YR 4.5/4 yellowish brown

Dry: 10YR 6.5/2 light brownish gray

Interval pH: 8.5

Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

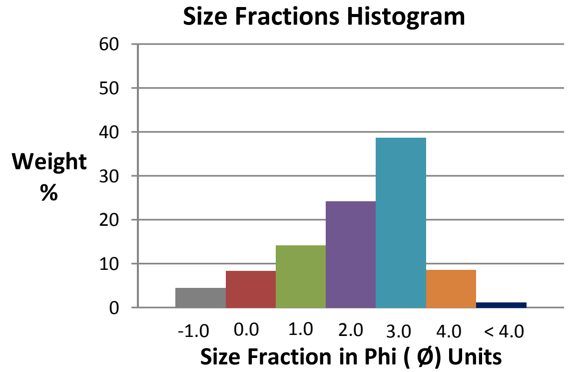
Sample Interval: -40 to -45 cm **Interval Depth Below Surface:** 100 to 105 cm

Stratum: Pebble lens

Date Collected: 05/25/2011 **Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	38.0	5	Granule plus rock fragments	Wall/ceiling rock pieces up to 40 mm long; vegetative debris; coal
18	1.00	0.0	70.1	8	Very coarse sand	Sandstone granules; vegetative debris; coal
35	0.50	1.0	118.4	14	Coarse sand	Sandstone granules; vegetative debris; coal
60	0.25	2.0	201.9	24	Medium sand	Grain granules; vegetative debris; coal;individual grains angular to sub-angular
120	0.125	3.0	322.5	39	Fine sand	Grain granules; individual grains angular to sub-angular; ½ one-half quartz grains frosted
230	0.0625	4.0	71.8	9	Very fine sand	Grains angular to sub-angular; little frosting of quartz grains
<230	<0.0625	<4	10.3	1	Silt/Clay	Grains angular to sub-angular; almost no frosting of quartz grains

Total Sample Weight:	833.0
Standard Deviation:	100.9
Median:	71.8
Mean:	119.0
Skew:	1.3
Sorting:	2.5



Interval Munsell Color:

Wet: 10YR 4/2 dark grayish brown

Dry: 10YR 6/3 pale brown

Interval pH: 8.4

Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

Sample Interval: -45 to -50 cm **Interval Depth Below Surface:** 105 to 110 cm

Stratum: Pebble lens (Combination of both pebble lense and non-pebble lens portions)

Date Collected: 05/25/2011 **Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	109.5	10	Granule plus rock fragments	Wall/ceiling rock pieces up to 20 mm long; charcoal; red baked shale
18	1.00	0.0	62.6	6	Very coarse sand	Sandstone granules; red baked shale; charcoal
35	0.50	1.0	194.0	18	Coarse sand	Sandstone granules; abundant vegetative debris; red baked shale; charcoal
60	0.25	2.0	351.0	32	Medium sand	Grains angular to sub-angular; vegetative debris
120	0.125	3.0	302.3	28	Fine sand	Grains angular to sub-angular
230	0.0625	4.0	61.4	6	Very fine sand	Grains angular to sub-angular
<230	<0.0625	<4	2.3	0	Silt/Clay	Grains angular to sub-angular

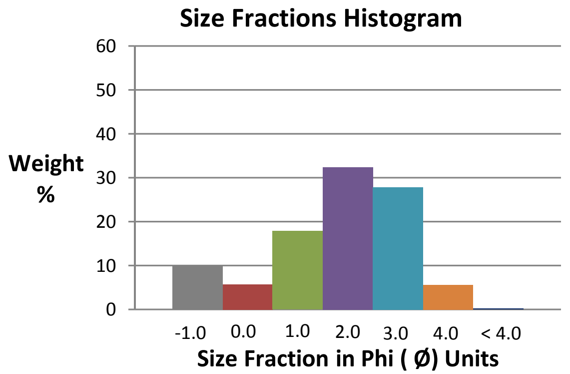
Total Sample Weight:	1083.1
Standard Deviation:	122.1
Median:	109.5
Mean:	154.7
Skew:	0.6
Sorting:	2.3

Interval Munsell Color:

Wet: 10YR 4/3 brown

Dry: 10YR 6/3 pale brown

Interval pH: 8.4



Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

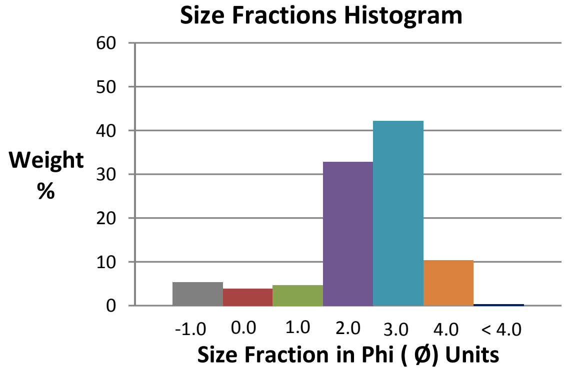
Sample Interval: -45 to -50 cm **Interval Depth Below Surface:** 105 to 110 cm

Stratum: Non-pebble lens portion of pebble lens

Date Collected: 05/25/2011 **Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	29.6	5	Granule plus rock fragments	Wall/ceiling rock pieces up to 20 mm long; charcoal; red baked shale
18	1.00	0.0	21.6	4	Very coarse sand	Sandstone granules; red baked shale; charcoal
35	0.50	1.0	26.1	5	Coarse sand	Sandstone granules; abundant vegetative debris; red baked shale; charcoal
60	0.25	2.0	180.1	33	Medium sand	Grains angular to sub-angular; vegetative debris
120	0.125	3.0	230.6	42	Fine sand	Grains angular to sub-angular
230	0.0625	4.0	56.6	10	Very fine sand	Grains angular to sub-angular
<230	<0.0625	<4	2.1	0	Silt/Clay	Grains angular to sub-angular

Total Sample Weight:	546.7
Standard Deviation:	82.9
Median:	29.6
Mean:	78.1
Skew:	1.2
Sorting:	3.0



Interval Munsell Color:

Wet: 10YR 4/3 brown

Dry: 10YR 6/3 pale brown

Interval pH: 8.4

Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

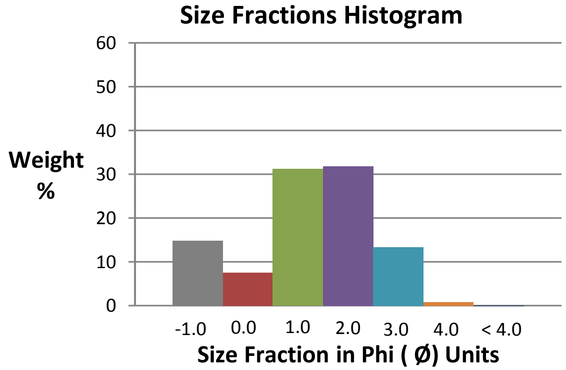
Sample Interval: -45 to -50 cm **Interval Depth Below Surface:** 105 to 110 cm

Stratum: Pebble lens excluding non-pebble lens portion

Date Collected: 05/25/2011 **Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	79.9	15	Granule plus rock fragments	Wall/ceiling rock pieces up to 45 mm long; vegetative debris; coal
18	1.00	0.0	41.0	8	Very coarse sand	Sandstone granules; vegetative debris; coal
35	0.50	1.0	167.9	31	Coarse sand	Grains angular to sub-rounded; coal
60	0.25	2.0	170.9	32	Medium sand	Grains angular to sub-rounded
120	0.125	3.0	71.7	13	Fine sand	Grains angular to sub-angular
230	0.0625	4.0	4.8	1	Very fine sand	Grains angular to sub-angular,; some frosting of quartz grains
<230	<0.0625	<4	0.2	0	Silt/Clay	Grains angular to sub-angular; extensive frosting of quartz grains

Total Sample Weight:	536.4
Standard Deviation:	64.9
Median:	71.7
Mean:	76.6
Skew:	0.5
Sorting:	5.9



Interval Munsell Color:

Wet: 10YR 5/2 grayish brown

Dry: 10YR 7/3 very pale brown

Interval pH: 8.4

Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

Sample Interval: -50 to -55 cm

Interval Depth Below Surface: 110 to 115 cm

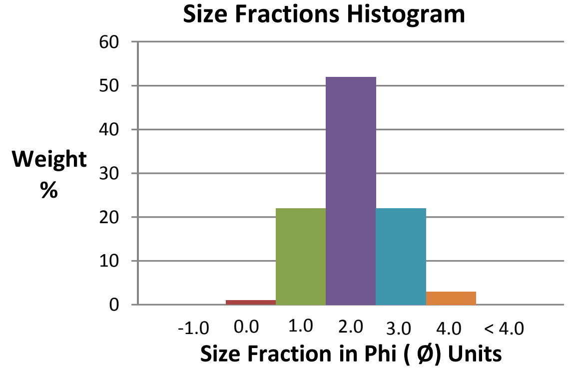
Stratum: 7

Date Collected: 05/25/2011

Collected By: Jack Fisher and Norman Smyers

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	1.3	0	Granule plus rock fragments	Wall/ceiling rock up to 20 mm; vegetative debris
18	1.00	0.0	6.4	1	Very coarse sand	Sandstone granules; abundance of vegetative debris
35	0.50	1.0	112.6	22	Coarse sand	Grain clusters; individual grains angular to sub-angular
60	0.25	2.0	273.2	52	Medium sand	Grain clusters; individual grains angular to sub-angular
120	0.125	3.0	115.0	22	Fine sand	Grains angular to sub-angular
230	0.0625	4.0	13.6	3	Very fine sand	Grains angular to sub-angular; moderate frosting of quartz grains
<230	<0.0625	<4	0.8	0	Silt/Clay	Grains angular to sub-angular

Total Sample Weight:	522.9
Standard Deviation:	93.9
Median:	13.6
Mean:	74.7
Skew:	1.5
Sorting:	10.9



Interval Munsell Color:

Wet: 10YR 4/3 brown

Dry: 10YR 6/3 pale brown

Interval pH: 8.4

Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

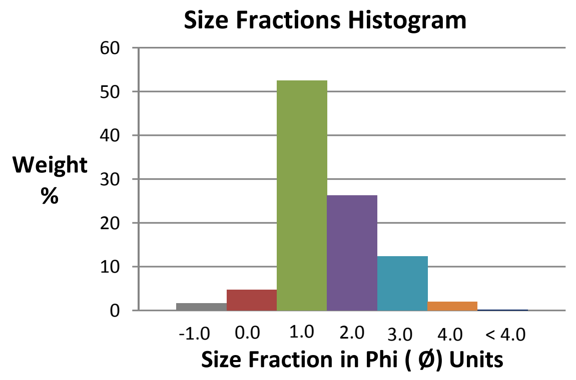
Sample Interval: -55 to -60 cm　　**Interval Depth Below Surface:** 115 to 120 cm

Stratum: 7

Date Collected: 05/25/2011　　**Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	9.8	2	Granule plus rock fragments	Sandstone granules; vegetative debris
18	1.00	0.0	28.7	5	Very coarse sand	Sandstone granules; abundant vegetative debris
35	0.50	1.0	316.1	53	Coarse sand	Grain granules; individual grains angular to sub-angular
60	0.25	2.0	158.4	26	Medium sand	Grains angular to sub-angular
120	0.125	3.0	74.9	12	Fine sand	Grains angular to sub-rounded; moderate frosting of some quartz grains
230	0.0625	4.0	12.5	2	Very fine sand	Grains angular to sub-rounded; moderate frosting of some quartz grains
<230	<0.0625	<4	1.3	0	Silt/Clay	Grains angular to sub-angular

Total Sample Weight:	601.7
Standard Deviation:	106.9
Median:	28.7
Mean:	86.0
Skew:	1.7
Sorting:	4.5



Interval Munsell Color:

Wet: 10YR 5/3 brown

Dry: 10YR 6/2 light brownish gray

Interval pH: 8.4

Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

Sample Interval: -60 to -65 cm **Interval Depth Below Surface:** 120 to 125 cm

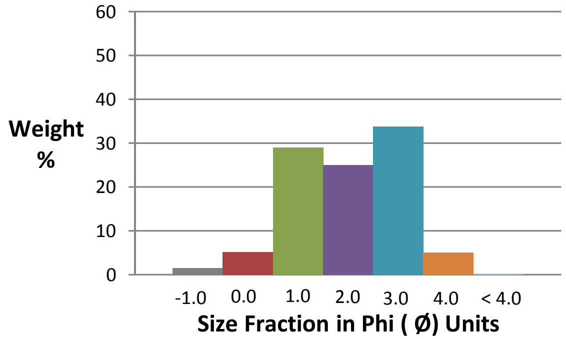
Stratum: 7

Date Collected: 05/25/2011 **Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	8.8	2	Granule plus rock fragments	One or two wall/ceiling rock pieces up to 10 mm long; abundant vegetative debris
18	1.00	0.0	29.6	5	Very coarse sand	Sandstone granules; some vegetative debris
35	0.50	1.0	165.6	29	Coarse sand	A few grain clusters; individual grains angular to sub-angular
60	0.25	2.0	143.2	25	Medium sand	A few grain clusters; individual grains angular to sub-angular
120	0.125	3.0	193.4	34	Fine sand	Grains angular to sub-angular
230	0.0625	4.0	28.9	5	Very fine sand	Grains angular to sub-angular; some frosting of quartz grains
<230	<0.0625	<4	1.1	0	Silt/Clay	Grains angular to sub-angular

Total Sample Weight:	570.6
Standard Deviation:	76.2
Median:	29.6
Mean:	81.5
Skew:	0.4
Sorting:	4.4

Size Fractions Histogram



Interval Munsell Color:

Wet: 10YR 5/4 yellowish brown

Dry: 10YR 7/1 light gray

Interval pH: 8.3

Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

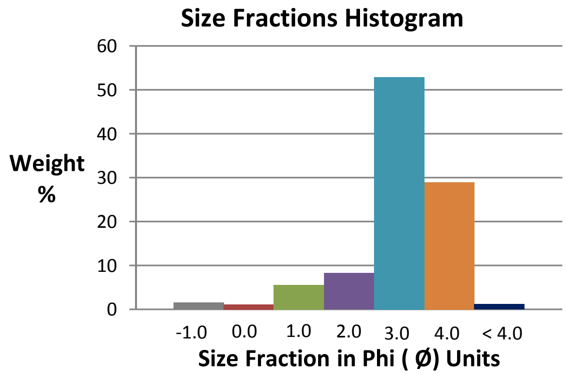
Sample Interval: -65 to -70 cm **Interval Depth Below Surface:** 125 to 130 cm

Stratum: 7

Date Collected: 05/25/2011 **Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	6.2	2	Granule plus rock fragments	Sandstone granules; vegetative debris
18	1.00	0.0	4.8	1	Very coarse sand	Sandstone granules; vegetative debris
35	0.50	1.0	22.2	6	Coarse sand	Sandstone granules; vegetative debris
60	0.25	2.0	32.4	8	Medium sand	Sandstone granules; vegetative debris; individual grains angular to sub-angular
120	0.125	3.0	208.0	53	Fine sand	Grains angular to sub-angular
230	0.0625	4.0	114.0	29	Very fine sand	Grains angular to sub-angular
<230	<0.0625	<4	5.0	1	Silt/Clay	Grains angular to sub-angular

Total Sample Weight:	392.6
Standard Deviation:	71.6
Median:	22.2
Mean:	56.1
Skew:	1.6
Sorting:	5.2



Interval Munsell Color:

Wet: 10YR 5/4 yellowish brown

Dry: 10YR 6.5/2 light yellowish gray

Interval pH: 8.2

Horseshoe Cave (24RB1094) Sieve Analysis
(South Wall Unit 2, Column B)

Sample Interval: -70 to -74 cm **Interval Depth Below Surface:** 130 to 134 cm

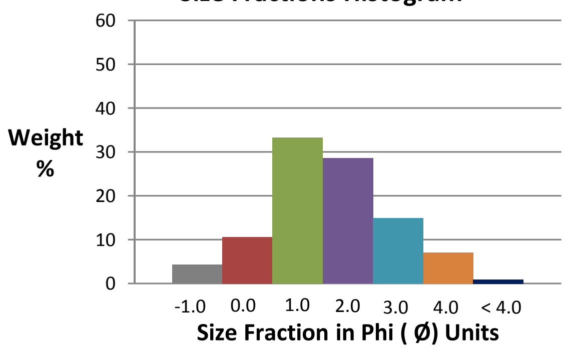
Stratum: 8

Date Collected: 05/25/2011 **Collected By: Jack Fisher and Norman Smyers**

U.S. Standard Sieve Mesh #	Size Class (mm)	Phi (ø) Units	Weight (gm)	Weight %	Wentworth Size Class	Remarks: Shape, composition, etc.
10+	2.00+	-1.0	23.2	4	Granule plus rock fragments	Large wall/ceiling piece 35 x 30 mm; ; abundant vegetative debris; sandstone granules; red burnt shale
18	1.00	0.0	56.6	11	Very coarse sand	Sandstone granules; some vegetative debris
35	0.50	1.0	177.2	33	Coarse sand	Grains angular to sub-angular
60	0.25	2.0	152.4	29	Medium sand	Grains angular to sub-angular
120	0.125	3.0	79.2	15	Fine sand	Grains angular to sub-angular
230	0.0625	4.0	37.7	7	Very fine sand	Grains angular to sub-angular
<230	<0.0625	<4	5.2	1	Silt/Clay	Grains angular to sub-angular

Total Sample Weight:	531.5
Standard Deviation:	60.6
Median:	56.6
Mean:	75.9
Skew:	0.8
Sorting:	2.6

Size Fractions Histogram



Interval Munsell Color:

Wet: 10YR 4/2 dark grayish brown

Dry: 10YR 7/3 very pale brown

Interval pH: 8.1

APPENDIX C

Site Reports Reviewed for the Horseshoe Cave Geoarchaeological Assessment

Site Reports Reviewed for the Horseshoe Cave Geoarchaeological Assessment*

County/Site Number	Site Name
Big Horn County	
24BH1053	21 Ranch
24BH0028	Commissary Spring Divide
24BH1895	Snow Fence Corral
24BH3555	Pen 70
24BH1625	*None listed*
24BH3539	Pen 52
Carter County	
24CT22	Medicine Rocks
Custer County	
24CR0244	Coal Miners 60 Home Site
Powder River County	
24PR37	*None listed*
24PR42	*None listed*
24PR292	Rough Creek Rock Shelter
24PR1706	*None listed*
24PR1562	Babbit Site
24PR1633	*None listed*
24PR1636	*None listed*
24PR1849	Home Creek Butte
24PR2618	*None listed*
Rosebud County	
24RB163	Mellow Winds Shelter
24RB179	St. John's Timber Sale Addendum
24RB0180	*None listed*
24RB0504	BP Site C
24RB0507	Timber Creek Way Cool Site
24RB1094	Horseshoe Cave/Finger Cave
24RB1968	Odell Drainage

*Copies of the above site reports were provided by the Montana State Historic Preservation Office.